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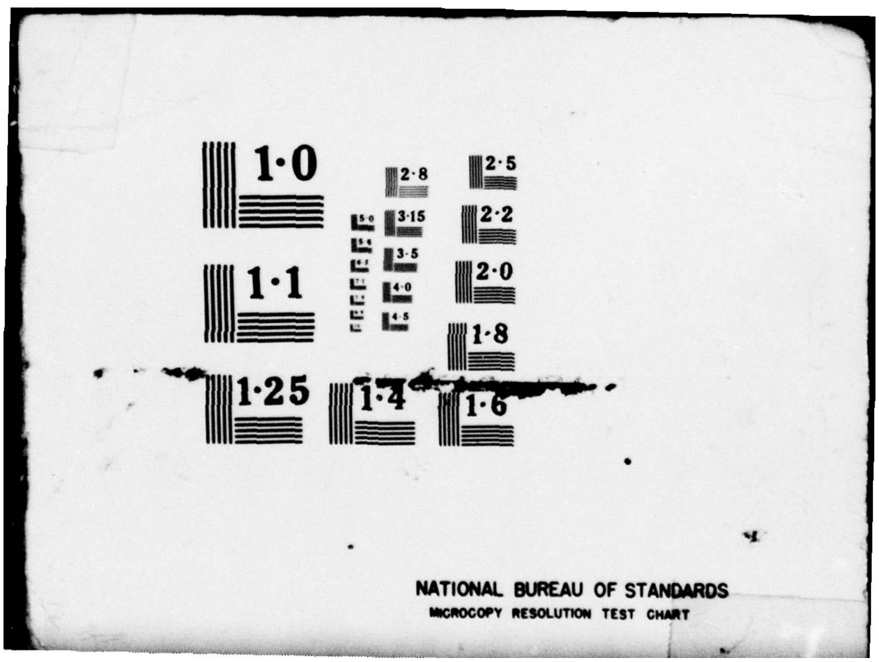
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MICROCOPY RESOLUTION TEST CHART

Report No. CG-D-25-79

RULES OF THE ROAD TRAINING INVESTIGATION

CAORF STAFF
NATIONAL MARITIME RESEARCH CENTER
KINGS POINT, NEW YORK 11024

NOVEMBER 1978

FINAL REPORT

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The U. S. Coast Guard project leader was Dr. John S. Gardenier and the project monitors were CDR Richard T. Hess and CAPT R. T. Sommer. LCDR John D. Bannan was of indispensable value as a navigation consultant. CAPT Virgil Rinehart was the project leader for the Maritime Administration.

16. Abstract

This report describes the results of experiments using the Maritime Administration Computer Aided Operations Research Facility (CAORF) ship maneuvering simulator to determine if training in the changes to the steering rules of the International Rules of the Road (1977) causes a difference in watch officer behavior in the crossing/meeting collision situations. An additional objective was to determine the differences between two ship types (VLCC and containership) in the same situations. A tighly structured, counterbalanced mixed design with one between- and three within-subject variables was applied to eight realistic experimental scenarios. All scenarios involved failure to give way, in five or twenty-five degree crossings, between a 25 knot containership and a 15 knot VLCC. A half-day, classroom training program, using a sound/slide presentation and case study discussions, was effective in increasing knowledge and understanding of the Rules changes. Transfer of training to the simulator did occur with the trained group. Consistency of performance (range to target ship at maneuver) was significantly improved, fewer course changes per maneuver were made, and better advantage was taken of the rule pertaining to ambiguous meeting/crossing situations by the trained group. The closest points of approach (CPA) for the containership sample were significantly larger than for the VLCCs, even though larger course changes were made by the VLCCs at approximately the same range (4 nm). Under conditions of restrictions to the right, the VLCC mariners made more non-right maneuvers than the containership watch officers and also appeared more concerned with oil rigs and fairway restrictions than with shoals.

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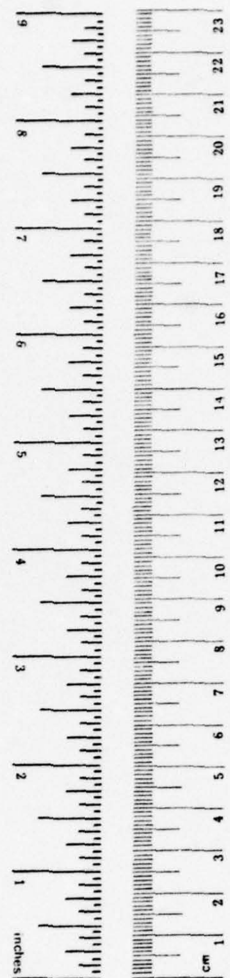
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

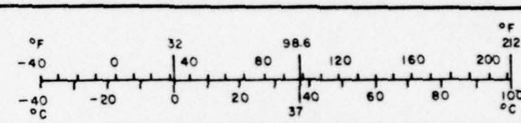
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The organization of this report is centered about the duality of both the experiment design and the analyses of the results. In reality, two interlocking studies were performed simultaneously; one related to training effects and the other to ship effects.

The introductory material which is found in Chapter 1 contains a composite description of the common source of the experiment and background information (i.e., literature search) as well as a description of the overall experiment design. In a similar manner, the Methodology Chapter (2) contains a common description of such items as experiment variables, scenarios, vessels, subjects, data collection techniques, etc.

Separate statistical analyses of the data were performed and, therefore, the results, discussions, and conclusions of Chapter 3 have been appropriately segregated by training and ship effects. Chapter 3 also contains a subsection for generalized considerations, that is, statistical and subjective findings which were common to both areas.

An executive summary has been included with this report for the purpose of presenting a capsule view of the more pertinent results and conclusions.

EXECUTIVE SUMMARY

1.1 BACKGROUND

The United States Coast Guard sponsored a Rules of the Road Training Investigation which made use of the ship maneuvering simulator at the Computer Aided Operations Research Facility (CAORF) at the National Maritime Research Center, Kings Point, New York.

The International Rules of the Road define actions to be taken by vessels in various circumstances, and the latest revision became effective in July 1977. Substantial changes affecting the actions of stand-on vessels in clear-cut crossing situations and in ambiguous crossing (nearly head-on) situations were incorporated. The rules now authorize more discretion for a mariner who finds himself in either of these types of potential collision encounters. It was felt that this investigation would provide some early insight into the actual manner in which these modified rules would be interpreted by experienced watch officers and whether or not the behavior of mariners would be different in these situations 1) if they were given training in the changes to the steering rules and 2) if they were handling different types of vessels.

1.2 OBJECTIVES AND EXPERIMENT DESCRIPTION

The experimental portion of the Rules of the Road Training Investigation took place at CAORF during the summer of 1977, immediately after the introduction of the changes to the rules. The objectives of the research were to determine:

- Whether the new Rules of the Road, especially Rule 17(a)(ii), would make any difference in collision avoidance behavior in crossing situations as opposed to behavior under the old rules which lacked that provision.
- Whether training in the new rules would affect the behavior.
- Whether the relative controllability of ownship (containership as opposed to very large crude carriers - VLCCs) would make a difference in the use of the new rules.

- Whether a small number of experimentally controllable variables would affect the behavior at issue.

Eighteen mariners (masters and chief mates) participated in eight one-hour scenario segments on the simulated bridge at CAORF. The eight segments were included within two 4-hour watches; one in the Gulf of Mexico and one off the Florida Straits. The mariners were experienced containership and VLCC watch officers and they sailed corresponding vessels during the experiment runs. Each scenario was essentially a crossing or head-on collision situation with one or more traffic ships. In each case one of the traffic ships, a give-way vessel, broke the rules and did not maneuver. The behavior of ownship, a stand-on vessel, was observed and measured. All mariners of the same background were subjected to identical scenarios. Differences were imposed between the scenarios for different ship classes, to accommodate for the differences in ownship speeds, allowing the essential characteristics in the scenarios to remain constant.

All runs were performed under conditions of unlimited visibility, calm wind and seas, daytime, with radar in operation. No bridge-to-bridge VHF communications was allowed.

The eighteen subjects were assigned to three groups for experiment purposes. These groups consisted of six VLCC mariners who received a specialized half-day classroom training program in the changes to the steering rules, six containership mariners in a similarly trained group, and six additional VLCC mariners within an untrained group. The untrained group previously had access to information about the rule changes through normal maritime channels but had not received specific instructions concerning them. The overall experiment design consisted of two comparisons, first, between the VLCC groups with and without training and second, between the ship type groups. The eight scenarios in which each mariner took part contained three variables (two levels). These variables were randomized between the runs and are described below;

- <u>Crossing Situation</u> - Either clear-cut, at approximately 25° reciprocal course angle between ownship and primary threat vessel, or ambiguous crossing, at approximately 5° reciprocal course angle. Both encounter geometries placed the threat vessel off the port bow of ownship.

- Maneuver Restriction - either a close-by right hand maneuvering restriction (but allowing sufficient maneuvering room), or no restriction. Restrictions took the form of oil rigs during the Gulf of Mexico watch and shoal water off the Florida Straits.

- Traffic Density - either low or high traffic density in the vicinity of the encounter, but no other vessels were so closely situated that they would destroy the applicability of the two ship encounter limitations of the Rules of the Road.

Training regarding the changes to portions of the Rules of the Road was accomplished at CAORF using materials generated specifically for this purpose and a moderator who was an experienced mariner and instructor of nautical science. The training consisted of a sound-slide presentation, a brief summary of the key points of the rule changes by the moderator, and an in-depth participatory discussion between the moderator and the trainees regarding a variety of case studies.

1.3 SIMULATOR DESCRIPTION

The experiment was conducted at the Computer Aided Operations Research Facility (CAORF), a sophisticated, state-of-the-art ship maneuvering simulator constructed by the U.S. Maritime Administration for controlled research studies of the man-ship-environment interfaces. A simplified cutaway of the simulator building is shown in Figure 1-1 and the relationship among the major CAORF subsystems is illustrated in Figure 1-2. The major subsystems are:

- Wheelhouse which contains a complement of actual marine hardware, including two late model radars.

- Central Data Processor which computes the motion of ownship in accordance with its known characteristics, stimulates the appropriate bridge indicators, and models the behavior of all other traffic ships.

- Image Generator which constructs the computer-generated visual image of the surrounding environment and traffic ships. The image is projected onto a cylindrical display screen for visual realism.

- Radar Signal Generator which synthesizes video signals to stimulate the bridge radar for the display of traffic ships and the surrounding environment in relation to ownship.

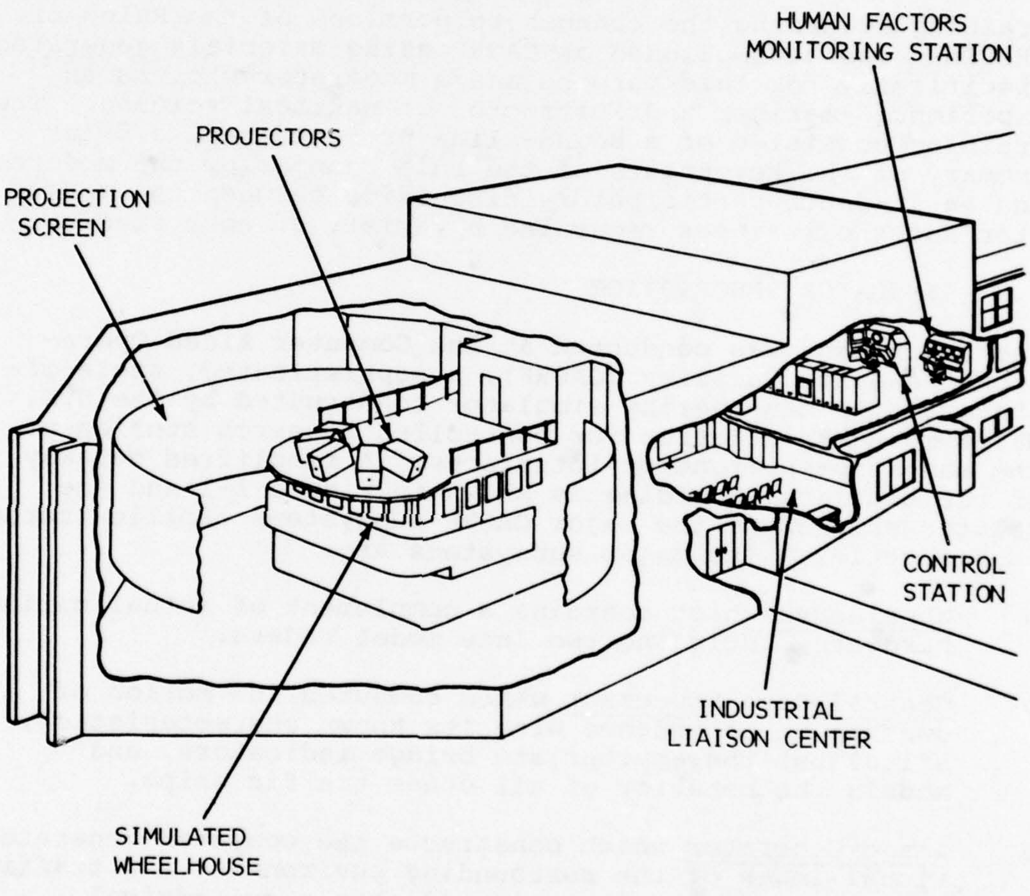


Figure 1-1. Cutaway View of CAORF Building

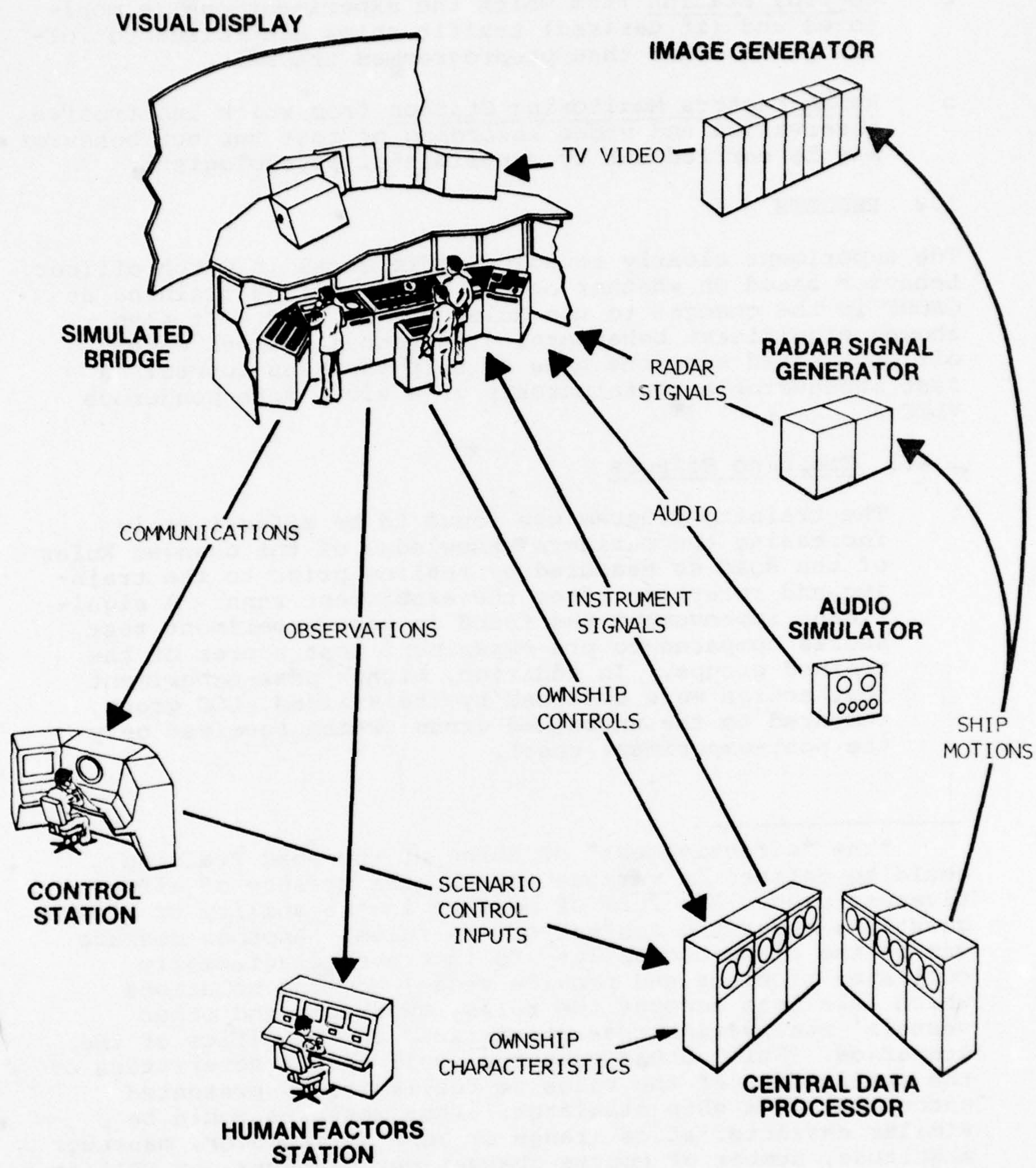


Figure 1-2. CAORF Simulator Subsystems

- Control Station from which the experiment can be monitored and (if desired) traffic ships controlled to follow paths other than preprogrammed tracks.

- Human Factors Monitoring Station from which unobtrusive observation and video recording of test subject behavior may be carried out by experimental psychologists.

1.4 RESULTS

The experiment clearly revealed differences in watch officer behavior based on whether or not they received training at CAORF in the changes to the Rules of the Road. It also showed significant behavioral differences between watch officers based upon the type of ship that was conned: a fast maneuverable containership or a slow, more ponderous VLCC.

1.4.1 Training Effects

- The training program was found to be effective* in increasing the mariners' knowledge of the changed Rules of the Road as measured by testing prior to the training and retesting after the experiment runs. A significant improvement was found in post-experiment test scores compared to pre-experiment test scores of the trained groups. In addition, higher post-experiment test scores were obtained by the trained VLCC group, compared to the untrained group (which received only the post-experiment test).

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*The "effectiveness" of Rules of the Road Training could be defined in various ways by the measure of effectiveness used. One form of measure is the ability to answer questions about the content of the rules. Another measure can be the classroom ability to interpret diagrammatic collision problems and provide vessel command solutions which take into account the rules, ownship's and other vessels' maneuvering characteristics, and specifics of the scenarios. Still other measures could be characteristics of the application of the rules to realistically presented encounters in a ship simulator; other measures could be similar characteristics (range or TCPA at maneuver, maneuver magnitude, number of course changes per maneuver, or CPA) at sea rather than on the simulator. The effectiveness measure used in this study were test scores and simulator applications of the Rules.

- A transfer of training to the simulator was shown. The trained mariners exhibited a consistency in their maneuvering range which is attributed to the training that they had received. This consistency in their maneuvering was measured by the mean of the standard deviations of the range at maneuver.

  The number of course changes per maneuver for the trained VLCC group was found to be smaller than for the untrained group and therefore, may also be attributed to training. The desirability of large recognizable course changes is fundamental to good seamanship and was underscored in the training program. A single maneuver is more recognizable than a series of small course changes which add up to the same overall maneuver magnitude. Therefore, the fact that the trained group accomplished their larger course changes with a significantly smaller number of changes per maneuver shows that they were more decisive than the untrained group and that there was a transfer of training to bridge behavior in this area, also.

  Rule 14 encourages interpreting an ambiguous crossing situation as a meeting situation, and this fact was emphasized in the training. The trained group took advantage of this rule change. This was indicated by the larger CPAs attained by this group, compared with the untrained group, for this type of crossing encounter. It was also shown that the trained group obtained significantly larger CPAs (for ambiguous encounters) when there were restrictions to starboard.

This experiment suggests that any training program which increases the mariners' knowledge of the new Rules of the Road, would most probably result in more desirable behavior patterns. Examples of such improved behavior are the consistency of maneuvering range and small number of course changes per maneuver, both of which were found to be related to overall knowledge of the changed rules.

1.4.2 Ship Type Effects

- The mean range at which the stand-on vessel watch officers made their escape maneuvers was found to be about 4 nm and independent of the type of ship or their training status regarding the changes to the Rules of the Road. The attained CPAs though were substantially different; i.e., larger for the containership masters compared with the VLCC officers. Since the size of the

maneuvers* was also significantly different (larger for the VLCC watch officers), analyses were performed "offline" to determine the CPAs that could be realized by both types of vessels. The anlyses were based on efficient maneuvering at various maneuver magnitudes when the actions were initiated at the mean range for all runs (4 nm). The results of these analyses indicate that the containership mariners could have achieved practically any CPA that they desired (1 to 3 nm) dependent on the size of the maneuver employed and the efficiency of the course change (number of changes per maneuver). The potential CPA available to these containership mariners at a 4 nm maneuvering range was large because of the turning and speed characteristics of their vessels and they, therefore, had a large "reserve CPA," i.e., a large difference between potential and achieved CPA. Alternatively, the analyses also indicate that the VLCC mariners could not have obtained much larger CPAs than they did on the simulator, when the maneuver was initiated at 4 nm. The analyses demonstrated that the best possible CPAs for the VLCC masters at this range were as low as 0.50 nm and as high as 0.95 nm, the latter resulting only from early and decisive 70° or 90° maneuvers. Based on the turning and speed characteristics of these vessels, the VLCC watch officers' behavior reflects the small reserve CPA that was available to them. The VLCC mariners attempted to abide by the changed rules by not maneuvering at extreme ranges (greater than 5 nm), but the inherently limited maneuverability of their vessels constrained their attained CPA. To determine the full impact of these implications, further graphical analyses were performed for a spread of ranges at maneuver, using the VLCC as the stand-on vessel. The results are shown in Figure I-3 and indicate that, for the fine crossing encounters of 5 and 25 degrees, a VLCC at 15 knots requires 8 miles to achieve a 2-mile CPA, using a maneuver magnitude of 55 degrees, the experimental mean for the VLCC trained group. Since these curves represent the optimal potential CPAs that are available, and recognizing that attained CPAs are always smaller, then even a 1-nm CPA can not be attained with a VLCC vessel using a 55° maneuver except when the range at maneuver is greater than 6 miles.

* Size of maneuver, or maneuver magnitude, is defined herein as the maximum total deviation from initial course during an encounter

Most mariners anticipate a give-way vessel taking action at a range of 5 or 6 nm and, therefore, maintain their course and speed at least to that point in an encounter when they are conning the stand-on vessel. This appears to present a paradox for the VLCC mariners. The VLCC officers could have attained the same "reserve CPA" as the more maneuverable vessels, but only by means of extensive maneuvering at ranges which are beyond the guideline (2 - 4.5 nm) indicated by commentary found in related maritime literature on the changed Rules of the Road.

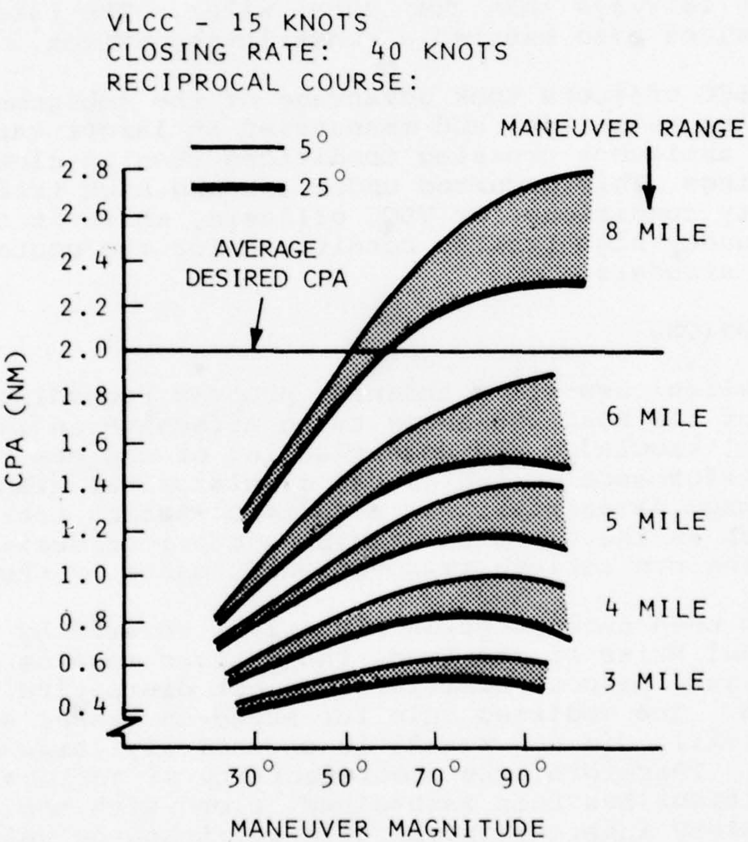

Figure 1-3. VLCC CPA vs Maneuver Magnitude at Different Maneuver Ranges

Most mariners anticipate a give-way vessel taking action at a range of 5 or 6 nm and, therefore, maintain their course and speed at least to that point in an encounter when they are conning the stand-on vessel. This appears to present a paradox for the VLCC mariners. The VLCC officers could have attained the same "reserve CPA" as the more maneuverable vessels, but only by means of extensive maneuvering at ranges which are beyond the guideline (2 - 4.5 nm) indicated by commentary found in related maritime literature on the changed Rules of the Road.

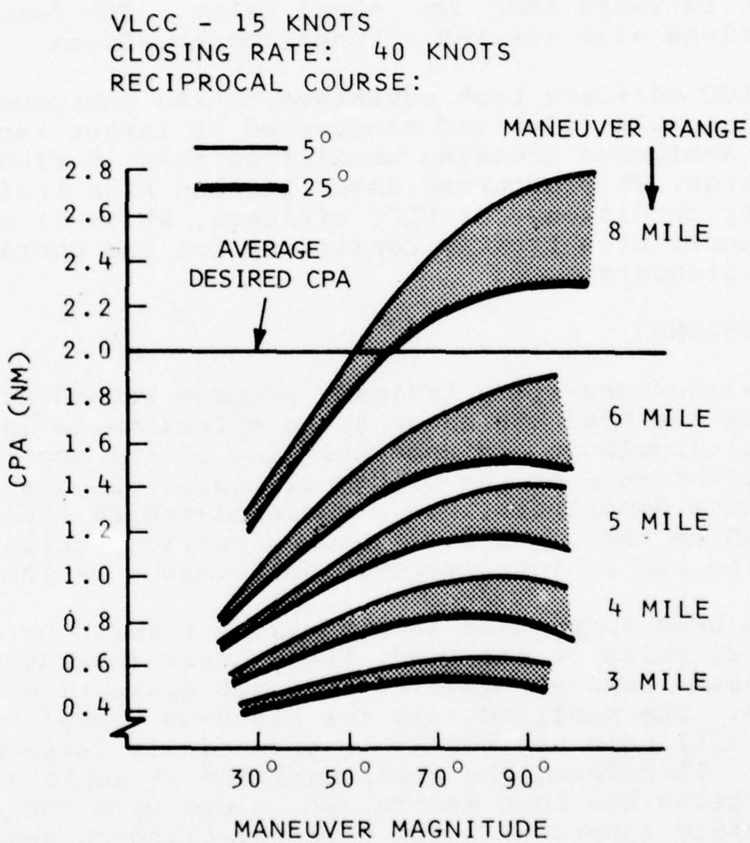

Figure 1-3. VLCC CPA vs Maneuver Magnitude at Different Maneuver Ranges

- The paradox resulting from the reserve CPA concept noted above apparently caused far smaller attained CPAs than the VLCC mariners themselves had indicated that they desired.

- The VLCC mariners were more concerned with the encounters containing restrictions on the right, which was indicated by the fact that they performed significantly more non-standard maneuvers* than the containership watch officers did. The VLCC officers also maneuvered at significantly larger ranges during these restrictive encounters compared with their maneuvering when no restrictions were present.

- The type of restriction had a differential effect for the VLCC watch officers. They performed a larger number of non-right maneuvers for oil rigs adjacent to safety fairways than for shoal water. The fairways themselves also exerted a constricting effect.

- The VLCC officers took advantage of the ambiguous crossing rule (14c) and maneuvered at larger ranges under ambiguous crossing conditions than in clear-cut crossings. This occurred under low and high traffic density conditions for VLCC officers, while it occurred only under high traffic conditions for the containership watch standers.

1.5 CONCLUSIONS

The sound-slide/case-study training program regarding the new Rules of the Road was shown to be effective in increasing the masters' knowledge and understanding of the new rules. Improved performance on the bridge simulator was also shown. These findings demostrate that a decision-making training program such as the classroom training provided during the investigation can achieve improved performance by the master.

It has also been shown that in situations covered by the International Rules of the Road, the changes regarding stand-on vessel responsibilities were not disruptive, as had been feared. The modified rule for stand-on vessel action, Rule 17 (a)(ii), did not result in excessively large maneuvering ranges. Therefore, the predictability of actions under these conditions has been maintained, along with the orderliness and safety inherent in the give-way/stand-on vessel concept.

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* Maneuvers to port or decreases in speed

The fine crossing situations between a high speed containership and a slower VLCC, when the latter is the stand-on vessel, is inherently difficult. The new Rules of the Road do not adequately address the situation with regard to the action of the stand-on vessel. The rules do not underscore encounters involving a "less maneuverable" vessel in open waters other than to allow a maneuver by that vessel when it becomes apparent that the give-way vessel had not taken appropriate action.

When the VLCC watch officer does react properly, in accordance with these new rules and his previous experience, he has placed himself into a situation in which the inherent maneuvering limitations of his vessel restrict his passing distance to a non-maneuvering give-way vessel. The attained CPA is then at a level which is considerably less than he desires.

The findings depicted in Figure 1-3, may well offer guidance for relevent court interpretations of Rule 17(a)(ii).

In the general situation though, the advantage of this new rule for the stand-on vessel is readily apparent since the situation no longer <u>must</u> deteriorate to extremis, where the give-way vessel cannot escape by his maneuver alone. At extremis, as defined, the situation has deteriorated so badly that neither vessel could avoid the collision by only one ship's maneuver. If the give-way vessel had not maneuvered prior to extremis, what assurance is there that it will ever maneuver?

In this regard, subjective debriefings of the watch officers revealed that the new rules actually legitimatized existing behavior. An overwhelming majority of the subjects indicated that they had reacted to the stand-on vessel experimental encounters in a manner similar to the way they would have handled them prior to the rule changes - they maneuvered prior to extremis.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The United States Coast Guard approved a Rules of the Road Training Investigation on 21 March 1977, which was to make use of the ship maneuvering simulator at the Computer Aided Operations Research Facility (CAORF) at the National Maritime Research Center, Kings Point, New York. The investigation was authorized by MIPR Z70099-7-72541.

The objectives of the research were to determine:

- Whether the new Rules of the Road, especially Rule 17(a)(ii), would make any difference in collision avoidance behavior in crossing situations as opposed to behavior under the old rules, which lacked that provision.
- Whether training in the new rules would affect the behavior
- Whether the relative controllability of ownship (containership as opposed to very large crude carriers - VLCC) made a difference in the use of the new rules.
- Whether a small number of experimentally controllable variables affected the behavior at issue

It was recognized that the first objective would have to be approached in a partially judgmental manner through a literature search and subjective evaluation of the test subjects since behavior under the old rules could not be easily evaluated experimentally once the new rules became effective. The remaining questions were to be answered by classical methods of experimental design including, hopefully, a convergence of statistical evidence and judgmentally reasonable explanations for experimentally observed behavior.

1.2 THE RULE CHANGES AT ISSUE

The International Rules of the Road are a comprehensive set of regulations for preventing collisions at sea. They define the actions to be taken by vessels in various circumstances and are intended to create orderly traffic situations. The latest revision to the rules took effect in July 1977 and included substantial changes affecting the actions of vessels in a stand-on crossing situation and in an ambiguous meeting (head-on) situation. In the past these situations have always been controversial and, despite a number of rule revisions, still create problems of subjective interpretation for the watch officer.

The latest revisions to the stand-on crossing situation, Rule 17, and head-on situation, Rule 14, state:

<u>Action By Stand-On Vessel (Rule 17)</u>

(a)(i) Where one of two vessels is to keep out of the way the other shall keep her course and speed.

(ii) The latter vessel may however take action to avoid collision by her maneuver alone, as soon as it becomes apparent to her that the vessel required to keep out of the way is not taking appropriate action in compliance with these Rules.

(b) When, from any cause, the vessel required to keep her course and speed finds herself so close that collision cannot be avoided by the action of the give-way vessel alone, she shall take such action as will best aid to avoid collision.

(c) A power-driven vessel which takes action in a crossing situation in accordance with subparagraph (a)(ii) of this Rule to avoid collision with another power-driven vessel shall, if the circumstances of the case admit, not alter course to port for a vessel on her own port side.

(d) This Rule does not relieve the give-way vessel of her obligation to keep out of the way.

Head-On Situation (Rule 14)

(a) When two power-driven vessels are meeting on reciprocal or nearly reciprocal courses so as to involve risk of collision each shall alter her course to starboard so that each shall pass on the port side of the other.

(b) Such a situation shall be deemed to exist when a vessel sees the other ahead or nearly ahead and by night she could see the masthead lights of the other in a line or nearly in a line and/or both sidelights and by day she observes the corresponding aspect of the other vessel.

(c) When a vessel is in any doubt as to whether such a situation exists she shall assume that it does exist and act accordingly.

Regarding Rule 17, the previous version of the rules required the privileged vessel to maintain her course and speed and to stand on until it became apparent that a collision could no longer be avoided by the action of the give-way vessel alone. These requirements have been eased in the new rules.

The new rules do contain a very important change in Rule 17(a)(ii). The interpretation of this rule in conjunction with Rule 17(a)(i) and (b) is a cause of concern to maritime regulatory agencies. The extremes of interpretation are:

- Rule 17(a)(ii) might be used by stand-on vessels as authority to break off at any time they wish. This could create a degree of anarchy since the actions of the stand-on vessel would be much less predictable. This could result in an increase in the number of collisions at sea.

- Rule 17(a)(ii) could be interpreted as a requirement for the stand-on vessel to stand on until just before that point in time beyond which it can, <u>by its action alone</u>, no longer avert a collision. This is a relief from the earlier requirement to stand on until collision cannot be averted by the action of the <u>burdened vessel alone</u>. In other words, the definition of the last safe moment to maneuver is made easier to judge, since it requires only knowledge of ownship maneuvering characteristics, and the success

of the collision avoidance maneuver does not require the cooperation of the give-way vessel under this interpretation.

The hypothesis has also been put forth that little difference in behavior will occur as a result of the rule changes since the stand-on vessel often took action earlier than prescribed in the old rules. The major rule changes in this context are a legalization of behavior that already occurs.

Rule 14 paragraphs (a) and (b) are substantially the same as under the old rules. Paragraph (c) has been inserted as an attempt to clarify the difficulties and variations in interpretations of what constitutes a head-on situation. At this point, if a doubt exists as to whether it is a head-on situation or not, the mariner can assume that it is and act accordingly.

The sum and substance of the two rules stated above is that more discretion is now authorized by the rules for a mariner that finds himself in a crossing or near crossing/meeting stand-on situation. It was felt that this investigation would provide some early insight into the actual manner in which these rules would be interpreted by experienced watch officers and whether or not the behavior of mariners would be different in these situations if they were given training in the changes to the steering rules. An additional research question was, would the maneuvering capability and size/class of ships that are involved make a difference in the behavior of the watch officers?

Simulation was the only practical way to perform such an experiment since it allowed critical situations to be created, and solutions attempted without actual jeopardy to personnel and equipment. It allowed many months of potential collision situations to be compressed into a short time period under controlled conditions for observation and measurement. The ship maneuvering simulator at CAORF, with its dynamic problem generation and digitally controlled visual/radar capabilities, was an ideal research tool for these purposes. A description of CAORF can be found in Appendix E.

1.3 EXPERIMENT DESCRIPTION

The experiment portion of the Rules of the Road Training Investigation took place at CAORF during July, August, and part of September 1977, immediately after the introduction of the changes to the rules.

Each of eighteen experienced mariners (masters and chief mates) participated in eight one-hour scenario segments on the simulated bridge at CAORF. The eight segments were included within two four-hour watches; one in the Gulf of Mexico and one off the Florida Straits. Each mariner was selected because he was an experienced watch officer for either a containership or a VLCC and, during the experiment runs, the computer ship model and visual presentation for ownship were adjusted to correspond with his real world ship's characteristics. Each scenario was essentially a collision crossing/meeting situation with one or more target ships. In each scenario one target ship, a give-way vessel, broke the rules and did not maneuver. The behavior of ownship, a stand-on vessel, was observed and measured. All mariners of the same background were subjected to identical scenarios. Differences were imposed between the scenarios for different ship classes, to accommodate for the differences in ownship speeds, allowing the essential characteristics in the scenarios to remain constant.

All runs were performed under conditions of unlimited visibility, calm wind and seas, daytime, with radar in operation. No bridge-to-bridge VHF communication was allowed.

Classroom (not simulator) training regarding the changes to portions of the Rules of the Road was conducted at CAORF, using materials generated specifically for this purpose. Six of the VLCC mariners, and six of the containership mariners were trained, while the remaining six VLCC watch officers were given no specific instructions regarding the changes.

1.4 BACKGROUND

Prior to July 1977, under the then existing Rules of the Road, it appeared to some that, rather than prevent collisions at sea, "Rule 21 not only allowed the development of collision situations, it encouraged and even appeared to command it" (Cahill 1965). A watch officer in a developing situation would observe a target vessel on the port bow steaming on a constant collision bearing and would be obliged to maintain course and speed until a point where collision could not be avoided by the action of the give-way vessel alone. What was this mariner to do? He had the unhappy dilemma of either waiting until his vessel was placed into a situation in which <u>both</u> ships in the encounter had to maneuver to avoid a collision (placed there by a vessel which had <u>not</u> as yet maneuvered - and consequently might very well not maneuver), or taking an earlier action

(i.e., maneuver) which could be legally interpreted as contrary to the Rules of the Road. Numerous court findings had enforced this stand-on concept as exemplified by the following: "The necessity for the privileged vessel to hold her course and speed is so pronounced that the courts have held the vessel blameless even when an early departure from the Rules might have avoided collision" (Cahill 1965).

Helmers (1963) stated, "These findings demonstrate that Rule 21, International Regulations, for objective reasons, does not correspond to practical needs .... Fortunately, practical navigators do not adhere to the letter of Rule 21. Practical navigators, rather, let themselves be governed by the latter part of the second sentence of Rule 21, taking such action in respect of another vessel acting irresponsibly as will best aid to avert collision. That is to say, practical navigators do not wait so long that the give-way vessel alone can no longer avoid collision. For nobody can with any degree of accuracy assess the maneuvering qualities of the other vessel."

It would appear then that the prudent mariner, when faced with this situation, before July 1977, would either retreat to the "good seamanship" concepts of the rules or employ another approach to "legalize" his actions prior to attainment of the extremis position. One method which would gain this end was not to allow the situation to develop at all, i.e., to maneuver out of the situation before the rules came into effect. And, just when did this finite point occur - just where do the rules become obligatory? Once again the rules are not definite, but this time tend to work in favor of the unhappy mariner noted above. Cahill (1965) provides a large group of references and interpretations, and summarizes with the comment, "all of the foregoing interpretations and decisions clearly state or imply that vessels can be within sight of one another and yet be outside the limit of applicability of the rules---a course change is allowable for the vessel on the starboard hand before he assumes the burden of being privileged. But it should be early, ---ample,---to the right."

Church (1974) states that action at "long" range has been the ordinary practice of seamen for decades. In fact, he points out that the October 1972 conference, which was held for the purpose of revising the Rules of the Road, attempted to propose just such a change which would recognize this <u>common practice</u> so that, "Any vessel which has established at long range that a risk of collision is liable to develop with another vessel may take substantial action at such long range to keep well clear." The prevailing opinion at the

conference though was that "long range action by seamen was undertaken outside of the Rules and therefore the Rules of the Road were not applicable, that the master took such action at his own risk, and that "long range" was not defined .... In brief, the practice was recognized, but a Rule would be conflicting and confusing."

Again, it appears that two of the avenues that were followed by the unhappy mariner prior to the adoption of the recent changes to the rules were: 1) to fall back on good seamanship guidelines and 2) to perform an early maneuver at an ill-defined point but "of course" prior to the rules being in effect.

But what if the watch officer wanted to follow specific guidelines that pertain to his type of ship in an actual encounter? Dunne (1972) suggested a formalization of information regarding shiphandling characteristics in the form of relative motion collision avoidance diagrams. These diagrams take the form of polar plots (range and bearing) from ownship which is placed at the center. Any point on the plot therefore represents a distance from ownship along a relative bearing line. A series of curves are superimposed on this plot with each curve representing the locus of points for a given relative closing speed between a target ship and ownship. These points represent the nearest allowable closing position (distance) to which a target ship on any relative bearing may be allowed to come before action is taken by ownship. The suggestion is made that an overlay of this diagram be available for use with the bridge radar and when the target ship reaches a position that intersects the curve, consistent with the relative velocity of the encounter, ownship should maneuver to starboard. The distance at any bearing of a given speed curve is dependent upon the encounter geometry and such ship characteristics as turning circle, loss of speed while turning and gain of speed when steadying up on the new course. The suggested range at maneuver for a 250,000 DWT tanker having a relative closing rate of 35 knots with a vessel approximately 20° on the port bow is 4 nm. This would result in a 1-mile CPA if the stand-on tanker alters course to starboard. For 38 to 40 knots of relative closing rate, the suggestion is approximately 4.5 nm.

J. M. Myers (1972) refers to a standard for collision avoidance maneuvering in possible extremis type situations developed by Commander Davis Lott. This standard has been taught at Navy Fleet Training Centers for many years and "experiments in ship simulators and actual experience (at sea) have shown them (Rules for Collision Prevention) to be

approximately 80 to 90 percent effective in establishing effective miss distances ....* This standard establishes guidelines which are completely in accordance with the Rules of the Road. The guidelines are set up in terms of number of Full Rudder Advances* at a given speed and a given rudder angle and, based on ship characteristics, calculations can be made to determine the range to target at maneuver. For the ship, encounter geometries, full right rudder, and speed parameters employed in this experiment at CAORF, Lott's suggestions result in the following:

Ship Type	Maneuver Range		
	Give-way Crossing	Head-on	Stand-on Crossing
VLCC	1.9 nm + CPA	2.4 nm + CPA	.9 nm
Containership	1.2 nm + CPA	1.5 nm + CPA	.6 nm

The preceding values are guidelines under the "old rules" to determine the maneuver range for extremis situations. Lott's suggestions for ownship give-way action could be turned around under the "new rules," to determine the point at which the give-way vessel has not taken appropriate action, allowing or permitting a maneuver by the stand-on vessel as ownship, although not taking ownship characteristics into account. For a CPA of 1 mile this permitted action point would be approximately 2.3 to 2.9 miles (crossing) or up to 3.4 miles (head-on).

Other authorities have made recent suggestions for guidelines to be used under the new Rule 17. Church (1974) indicated that the best legal advice at the October 1972 conference (called for the purpose of modifying the rules) was that courts would interpret the provision of Rule 17 (a)(ii) at about 2-1/2 miles to 5 miles depending upon the circumstances, size, and speed of the vessels involved. On

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*Full Rudder Advance - Distance gained in direction of original course from the time ship's wheel is first moved in the direction of the turn to the time when the ship is steadied upon the new course (change of 90°).

the other hand, Cockcroft and Lameijer (1976) suggested that, under the new rules, the distances that various "stages" apply will vary considerably, but that in a crossing situation the outer limit (i.e., rules coming into effect) might be of the order of 5 to 8 miles, with the outer limit for "permitted stand-on vessel action" at about 2 to 3 miles.

In summary, from the composite opinions of Dunne, Lott, Church, and Cockcroft/Lameijer it would appear that there is considerable variation in the "approved" distance for a permitted action by the stand-on vessel and this will certainly be the subject of future court interpretations. At present, however, the range of this action appears to be as low as 2.3 nm and as high as 4.5 nm, with possible legal interpretations going out to 5 nm.

CHAPTER 2

METHODOLOGY

2.1 OBJECTIVES OF THE EXPERIMENT

The experimental objectives of the Rules of the Road Investigation were:

- o To determine if differences in behavior exist in the handling of crossing and near crossing collision situations, between watch officers that have been trained in the new International Rules of the Road (July 1977) and those that have not.
- o To determine if differences in behavior exist between watch officers of two different classes of ships, in the handling of crossing and near crossing collision situations when operating under the new International Rules of the Road.

Additionally it was desired to determine if:

- o A moderate restriction to starboard maneuvering room influenced watch officer behavior for the conditions noted above.
- o Differences of high and low traffic density influenced the behavior.
- o Differences of ambiguous and clear-cut crossing influenced the behavior.

2.2 EXPERIMENT VARIABLES

The CAORF experiment was designed to investigate variables that were likely to affect stand-on vessel behavior under the new International Rules of the Road as delineated in the objectives (2.1). The comparison of behavior under the old and new rules could not be determined experimentally since the new rules were in effect at the time of experiment data collection on CAORF. An attempt was made, however, to compare the new rule behavior on CAORF with certain aspects of old rule behavior as shown in the research literature. If was felt by many authorities in the field that the changes to the Rules of the Road could result in situations in which stand-on vessel watch officers would use the latitude of Rule 17(a)(ii) as authority to "maneuver" at any

time that they might wish, resulting in completely unpredictable behavior and destruction of the stand-on vessel concept. This experiment attempted, in part, to assess the behavior of VLCC and containership watch officers in this regard.

2.2.1 Training

It was felt that training in the new rules might have a significant impact on the manner in which the watch officer behaves. Two levels of the training variable were used: 1) without Training and, 2) with Training. The No-Training group received no instruction in the changes to the Rules of the Road. They were informed that they were to operate under the new rules, which were in effect at the time of their runs on the simulator. The Trained group, conversely, received a structured non-simulator training program addressing the major rule changes that pertain to the stand-on vessel. The content of the training program is discussed in paragraph 2.6. Both groups received the basic CAORF indoctrination and familiarization training.

2.2.2 Ship Type

Ships vary widely in their handling characteristics. The largest differences in stand-on vessel behavior should occur for situations in which the relative maneuverability of the stand-on and give-way vessels differ greatly, i.e., 1) the stand-on vessel is a highly maneuverable type and the give-way vessel is a poorly maneuverable type; and, 2) the converse situation. In regard to these two situations, a VLCC stand-on vessel might be expected to take earlier action than a containership stand-on vessel, so as to be able to avoid the collision by its maneuver alone. Under the new rules, the point at which stand-on vessel action is permitted occurs when the target ship fails to take appropriate action. Failure to take appropriate action may logically be determined at an earlier point when the give-way vessel is a VLCC than when it is a containership. Hence, these two basic situations may result in wide differences in stand-on vessel behavior.

Two levels of this variable were investigated: 1) the stand-on vessel (ownship) is a VLCC and the give-way vessel a containership; and, 2) the stand-on vessel (ownship) is a containership and the give-way vessel a VLCC.

2.2.3 Crossing Situation

The demarcation line between a crossing and head-on situation is not clearly stated in the rules. As a result, ambiguous situations exist that are classified by some masters/mates as crossing and by others as head-on. This area of ambiguity generally exists when reciprocal collision course differences between two ships are between 5° and 10°. Widely varying behavior may result in this situation since some officers who define the situation as crossing will behave in accordance with the stand-on vessel provisions of the new rules, while others will follow the head-on rule, 14C. Hence, this variable was identified as important to the investigation of the new rules affecting stand-on vessel behavior.

Two levels of this variable were investigated: 1) clear-cut crossing situations with reciprocal course differences of 20° to 30°; and 2) ambiguous situations with reciprocal course differences of between 5° and 10°.

2.2.4 Maneuver Restrictions

The new Rule 17 which addresses the stand-on vessel actions suggests that collision avoidance maneuvers be made to starboard. Although this type of maneuver has historically been associated with good seamanship, it had not previously been explicity delineated in the Rules of the Road. It was felt that a close-by right maneuver restriction, although allowing maneuvering room to starboard, might affect the stand-on vessel's behavior in this regard.

Of increasing concern to the merchant marine is maneuverability of very large vessels, such as VLCCs. The ship handling characteristics of these vessels together with limitations imposed by their draft might greatly affect the actions taken by mariners controlling these large vessels. Because of the possible effect of a right maneuver restriction, as well as its differential effect on ship type, this variable was identified as relevant to the investigation.

Two levels of maneuver restrictions were investigated: 1) no maneuver restrictions, i.e., virtually open sea conditions; and, 2) close-by right maneuver restrictions. The right maneuver restriction was intended to be a concern to both types of ships involved in the experiment and was placed at about 4 to 5 nm. The restriction allowed sufficient room for ownship to make right maneuvers.

2.2.5 Traffic Density

The Rules of the Road direct the actions of the stand-on vessel only when it is involved in a two-ship encounter, that is, when no other nearby vessels interfere with the potential actions to be taken by the give-way or stand-on vessels. However, other ships in the general vicinity of the encounter may have an indirect effect on the actions taken by the stand-on vessel. This may result from a variety of factors associated with increased traffic density, such as increased watch officer workload. Hence, traffic density was identified as an important experimental variable.

Two levels of traffic density were used: 1) low traffic density consisting of two-ship encounters with no other contacts in the vicinity; and, 2) high traffic density encounters with a variety of contacts in the vicinity. The low traffic situations presented were isolated one-on-one encounters. The high traffic situations also presented a one-on-one encounter, although with other non-interfering traffic in the vicinity. The high traffic situations were based on a study of actual at-sea encounters.

2.3 EXPERIMENT DESIGN AND ANALYSIS

2.3.1 Experiment Model

Five independent variables, of two levels each, were investigated by this experiment. An analysis of variance, J. L. Myers (1972), for a 2 x 2 x 2 x 2 mixed design (one between- and three within-subject variables) was used, in each of two parts. The between-subject(s) variables were: 1) training and 2) ownship type (note: ownship was always the stand-on vessel). Each of the two parts of this analysis investigated one of these between-subject variables. The first part of the analysis, Figure 2-1, investigated the training variable. Ownship was a VLCC in both groups. It was anticipated that the training program would be most meaningful for the VLCC masters. The second part, Figure 2-2, investigated the effect of ownship type - VLCC versus containership. Both of these groups received training. A disadvantage of this approach was the lack of a "trained vs. no-training" comparison for the containership watch officers. The major advantage of this approach was the use of three between-subject groups rather than four, permitting a larger number of subjects per group in the simulator time available (i.e., greater power in the test). The three within-subject variables (traffic density, crossing situation and maneuver

Between "S" Variables (6 S's each)	Within "S" Variables							
	Situation Complexity (Traffic Density)							
	Simple				Multiple			
	Clear-Cut		Ambiguous		Clear-Cut		Ambiguous	
	Maneuver Restrictions		Maneuver Restrictions		Maneuver Restrictions		Maneuver Restrictions	
	Yes	No	Yes	No	Yes	No	Yes	No
Training (VLCC Masters)								
No Training (VLCC Masters)								

Figure 2-1. Training Effect Design

Between "S" Variables (6 S's each)	Within "S" Variables							
	Situation Complexity (Traffic Density)							
	Simple				Multiple			
	Clear-Cut		Ambiguous		Clear-Cut		Ambiguous	
	Maneuver Restrictions		Maneuver Restrictions		Maneuver Restrictions		Maneuver Restrictions	
	Yes	No	Yes	No	Yes	No	Yes	No
VLCC Masters (Training)								
Containership Masters (Training)								

Figure 2-2. Ownship Effect Design

restrictions) of two levels each, complete the design. These variables were identical for the two parts of this analysis.

This combination of two between- and three-within subject(s) variables yields 24 sets of conditions. This particular design was selected on the basis of: 1) the need for two between-subject variables (ship type and training); 2) limitations on the number of subjects, VLCC and total; 3) upper limit on the number of simulator hours for data collection; 4) the use of a four-hour watch scenario configuration.

The design used 18 subjects--12 VLCC watch officers and 6 containership watch officers. Each subject stood watch on the bridge during eight encounter segments requiring stand-on vessel action. These eight segments, which represent all combinations of the within-subject independent variables, were configured in the form of two four-hour watches. The three independent variables were balanced across the two four-hour watches (see Figure 2-3). The intent of this balancing was to minimize the learning effects of presentation order across the watch conditions. The order in which each watch officer stood the two watches was also randomized across the subjects.

2.3.2 Performance Measures

The investigation was designed to evaluate differences in behavior as a function of the experimental conditions. Several performance measures which can be considered to be dependent variables were to be evaluated due to the complexity of the experimental situation and likely behavior. These dependent variables were: 1) range between the stand-on and give-way vessels when the stand-on vessel maneuvered; 2) closest point of approach (CPA) between the vessels, and; 3) type and number of stand-on vessel maneuvers, including magnitude of course change, speed change, left or right maneuver, and maneuver description. These are the major parameters that describe the actions of the stand-on vessel watch officer. A variety of other variables were also monitored for evaluation including: 1) radar use behavior; 2) other tasks performed by the watch officer; 3) interview data following each one-hour watch segment and following the two four-hour watches.

2.3.3 Statistical Analysis

The experiment data were subjected to several types of statistical analyses. The primary statistical method used was an analysis of variance for a mixed design, in two

parts, with each part containing one between- and three within-subjects variables. The first part investigated the between-subject variable of training, while the second part investigated the between-subject variable of ownship type. These analyses of variance were performed for the principal performance measures of range to the threat vessel at time of maneuver and CPA attained to the threat vessel, to test the null hypothesis regarding main effects and interaction effects. The 0.10 level of probability was used as the criterion for statistical significance. In addition to analyses of variance, other statistical tests were performed on the data and are described in Appendix B.

2.4 SCENARIO AND VESSEL DECRIPTIONS

2.4.1 Scenario Design Considerations

The experiment task for each of the 18 subjects was to stand two four-hour watches on the CAORF bridge. From an experimental standpoint, each of the subjects participated in eight experiment runs of approximately one-hour duration. Each run consisted of a scenario with ownship and one or

Watch Conditions				
WATCH	HOUR	MANEUVER RESTRICTION	SITUATION COMPLEXITY	CROSSING SITUATION
A-GULF PORT (GALVESTON)	1	YES	SIMPLE	CLEAR-CUT
	2	YES	MULTIPLE	AMBIGUOUS
	3	NO	SIMPLE	AMBIGUOUS
	4	NO	MULTIPLE	CLEAR-CUT
B-STRAITS OF FLORIDA (LITTLE BAHAMA BANK)	1	NO	MULTIPLE	AMBIGUOUS
	2	NO	SIMPLE	CLEAR-CUT
	3	YES	MULTIPLE	CLEAR-CUT
	4	YES	SIMPLE	AMBIGUOUS

Figure 2-3. Conditions for Scenario Segments of the Two Four-Hour Watches

more traffic ships. The traffic ships progressed on predetermined courses and speeds, and if they maneuvered they did so at predetermined times. Ownship was allowed to maneuver as directed by the watch officer. The watch officers were to maintain the ship's course and speed until it was necessary to maneuver for collision avoidance purposes. In this manner a two-ship encounter situation developed as the scenario progressed and one collision situation, in which the give-way vessel did not maneuver, occurred during each scenario. The watch officer on ownship, as the stand-on vessel, had to take action to avoid the collision.

The selection and design of scenarios was considered to be of critical importance in two respects: first, the scenarios had to be accepted as realistic by the experienced test subjects in order to elicit behavior similar to what would be expected at sea; second, the scenarios had to be tightly structured in the sense of containing precisely the elements called for by the experiment design and minimizing extraneous factors that might affect the behavior and confound the experiment analyses.

The procedure used, which is recommended for future experiments, derived the experiment scenarios from actual at-sea situations. The first step was to define the experiment designs (Figures 2-1 and 2-2). This dealt with balancing the conditions across the series of runs. Second, a serach was made of recorded radar-scope images of actual at-sea situations in order to locate situations that closely approximated the desired scenarios. Selection of the at-sea situations from which the final experiment scenarios were modeled, was based on the level of correspondence between the actual situation and that desired in the experiment. The radar images were painstakingly compiled as dynamic, sequential, multi-vessel interaction plots. Minor modifications sought to provide the necessary experiment control by eli minating confounding elements and adding elements crucial to the experiment design. These scenarios comprised the complex situations in the experiment, i.e., four of the eight runs. The remaining four runs were simple, and completely fabricated.

Finally, two experienced mariners - one staff and an active sailing consultant "test-drove" each of the scenario runs and suggested slight adjustments to achieve the correct "feel" to the situations.

The experiment conditions of the three within-subject variables were balanced across the two watches (see Figure 2-3), and all combinations were present in the two watches.

Particular care was taken to ensure continuity between the four scenario segments of each watch. Each watch segment, although an independent scenario, was constructed to enable the stringing together of four segments into one near continuous watch. Ownship required only minor position adjustments to initialize the succeeding run, regardless of maneuvers used in the preceding segment.

Two versions of each watch were developed: 1) ownship as a 15 knot VLCC with a 25 knot containership as primary target and; 2) ownship as a 25 knot containership with a 15 knot VLCC as primary target. The two versions of each watch were identical with respect to the experimental treatments. They differed in terms of: 1) ownship and target types; 2) minor variations in geographical position during the watch; 3) distance covered by ownship due to differences in speed; and 4) relative ranges and bearings to the various contacts as a function of time. The other vessels in the complex traffic segments were essentially identical in both versions with regard to their courses, speed, and positions relative to the collision point. The time of collision (relative to segment start) was the same in both versions.

2.4.2 Chaff Targets

In each watch segment the subject faced a collision situation in which the give-way vessel failed to take action and he had to maneuver to avoid a collision. For purposes of experiment control, the primary target, i.e., the give-way vessel that failed to maneuver, was always the same type of ship proceeding, at the same speed, and at either of two approach angles. Without an imposed subterfuge, the subjects would likely recognize a scenario pattern and immediately identify the primary target within each run, after participating in several segments. Knowing that all give-way vessels were unlikely to maneuver could have caused unorthodox behavior by the subject. Therefore, chaff (i.e., deception) targets were inserted into the scenarios to mask the primary target. The chaff targets looked and acted like the primary target, and were on an initial collision course with ownship. The chaff targets, which were give-way vessels, maneuvered well before the collision point, as would normally be expected of a give-way vessel. The order of chaff targets versus prime target was randomized throughout the

segments, therefore, the subjects did not know which was the primary target until it failed to take appropriate action.

2.4.3 Watch A - Gulf Port

The Gulf Port watch occurs outbound from Port Arthur to the Florida Straits. The watch begins about 85 nm southeast of Texas Point in the safety fairway (an area in which no fixed structures may be emplaced). The first two hours of the watch occur with ownship traveling southeast in the fairway (see Appendix A, Figures A-1 and A-2) with maneuver restrictions (oil rigs) on the starboard side at about 4 nm. Ownship changes course in the third segment and heads toward the Tortugas. No maneuver restrictions are present during the last two segments of this watch (Appendix A, Figures A-3 and A-4).

The maneuver restrictions were constructed by locating oil rigs near the fairway. The positions of the inserted oil rigs were added to the appropriate navigation charts that were used by the watch officers. Repositioning of oil rigs is a common practice in this area of the Gulf.

The position and actions of the chaff targets are readily discernible from the figures. As can be seen, one or more chaff targets were inserted into each segment.

The watch version shown in Appendix A, Figures A-1 through A-4 depict the A Watch, VLCC ownship (V), with the four segments designated A1V through A4V. The alternate version of this watch has the containership (C) as ownship and the VLCC as the target. The four segments of this version (A1C through A4C) are shown in Appendix A, Figures A-5 through A-8. Comparison of the track charts for both versions of the A-Watch illustrate their similarities and differences.

2.4.4 Watch B - Matanilla Shoal

The B-Watch occurs in the northern part of the Florida Straits near the Matanilla Shoal area. Ownship is traveling northeast across the Straits of Florida from the coast of Florida to the Matanilla Shoals buoy, and then maneuvering right towards Europe. This track is relatively common for ships traveling between European and Gulf Ports. Considerable traffic is encountered in this area due to: 1) the coastal United States trade; 2) the Bahama Islands trade ; 3) the Northwest Providence Channel trade; and 4) traffic passing through the straits. The first two watch segments (B1V and B2V, Appendix A, Figures A-9 and A-10) occur under open sea conditions, virtually beyond sight of land or any

maneuvering restrictions. The two remaining segments (B3V and B4V, Appendix A, Figures A-11 and A-12) occur near the Matanilla Shoals buoy with maneuvering restrictions on the starboard side of ownship consisting of shoals at a range of about 4½ nm.

Figures A-9 through A-12 show the experimental conditions of each watch segment, as well as the realistic nature of the scenario. The tracks of all vessels, including the primary targets, are logical for this area. Existing shoals were used to provide the right maneuver restrictions.

The alternative version of this watch (B1C through B4C, Figures A-13 through A-16) with ownship as a containership, differs in the same manner as discussed previously regarding Watch A.

2.4.5 Non-Variable Scenario Conditions

The environmental conditions during all segments of each of the four-hour watches were similar. The watches occurred during the daylight hours with excellent visibility (i.e., about 12 nm). No current or wind effects were included. In addition, no VHF bridge communication was allowed and the Collision Avoidance System on the bridge was defined as "inoperative". The subjects were primarily concerned with collision avoidance, and navigation tasks were relatively minor. Although LORAN fixes were available during each segment, none were ever requested.

It is felt that all of the above conditions resulted in well-controlled scenarios pertinent to the experiment objectives.

2.4.6 Vessels' Characteristics

- VLCC
- Containership

One of the variables established for the Rules of the Road experiment was the class of ship used as ownship. Two ships were incorporated into the CAORF simulator for this purpose. The hydrodynamic characteristics of a 250,000 DWT, 1085-foot long VLCC was utilized as one of the ships and those of a 32,360-ton displacement, 638-foot long containership was used as the second.

Table 2-1 shows the primary characteristics of the VLCC and Table 2-2 shows those of the containership. Turning circle and crash stop information was also determined for both

TABLE 2-1

VLCC CHARACTERISTICS

Measure	Value
Length	1035'
Beam	170'
Depth	84'
Draft	65' 5-3/4"
Sea Speed	16 knots at 90 RPM -55 RPM (reverse)
Displacement	286,000 tons
Dead Weight	250,000 tons
Eye-Height -Location	75' above waterline 135' forward of rudder

TABLE 2-2

CONTAINERSHIP CHARACTERISTICS

Measure	Value
Length	638'
Beam	100'
Depth	61'
Draft	32.8'
Sea Speed	25 knots at 105 RPM -60 RPM (reverse)
Displacement	32,360 tons
DWT	27,000 tons
Eye-Height -Location	77' above waterline 225' forward of rudder

ships, and are shown in Figures 2-4 through 2-7.

2.5 TEST SUBJECTS

As described previously, the experiment design for the investigation required two between-subject variables; namely, training versus no training and VLCC versus containership. It was anticipated that the Rules of the Road training program would be most meaningful for VLCC watch officers , i.e., for the larger, less maneuverable ship, therefore the training variable was selected for that ship class. Six VLCC watch officers were trained in the pertinent steering sections of the new rules while six other VLCC mariners were left "untrained". Six containership watch officers were also trained for the purpose of making a ship type comparison with the trained VLCC officers.

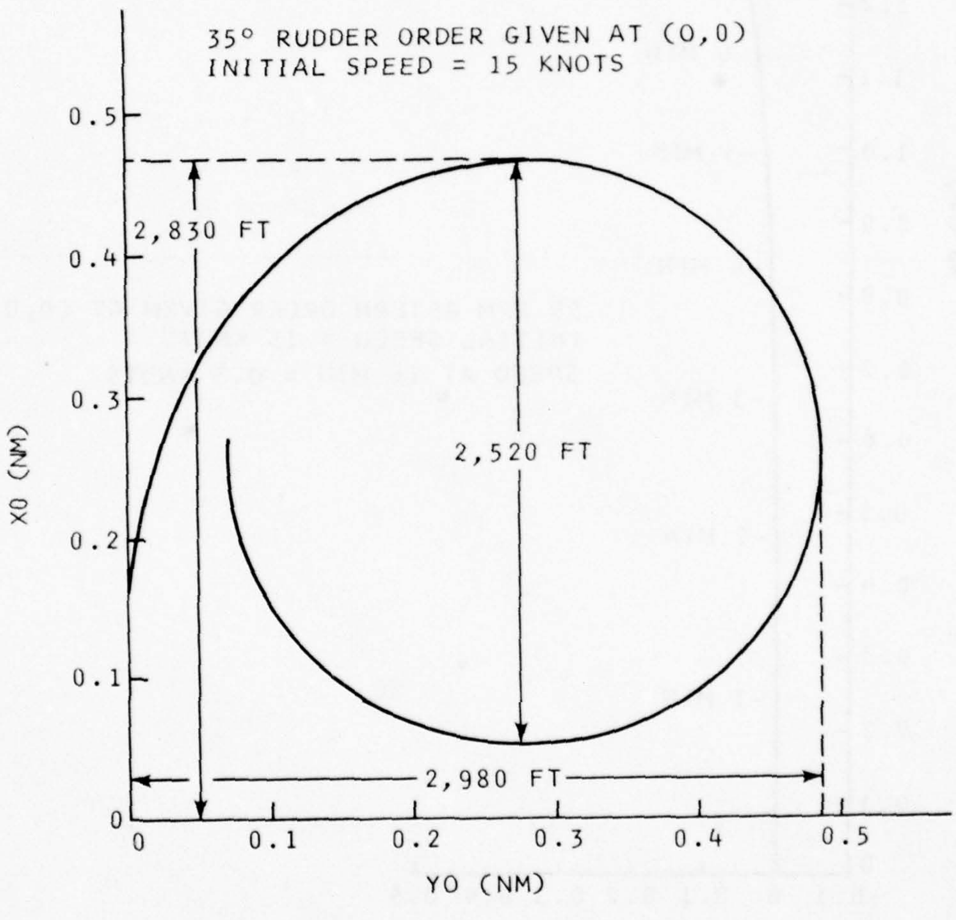


Figure 2-4. VLCC Turning Circle

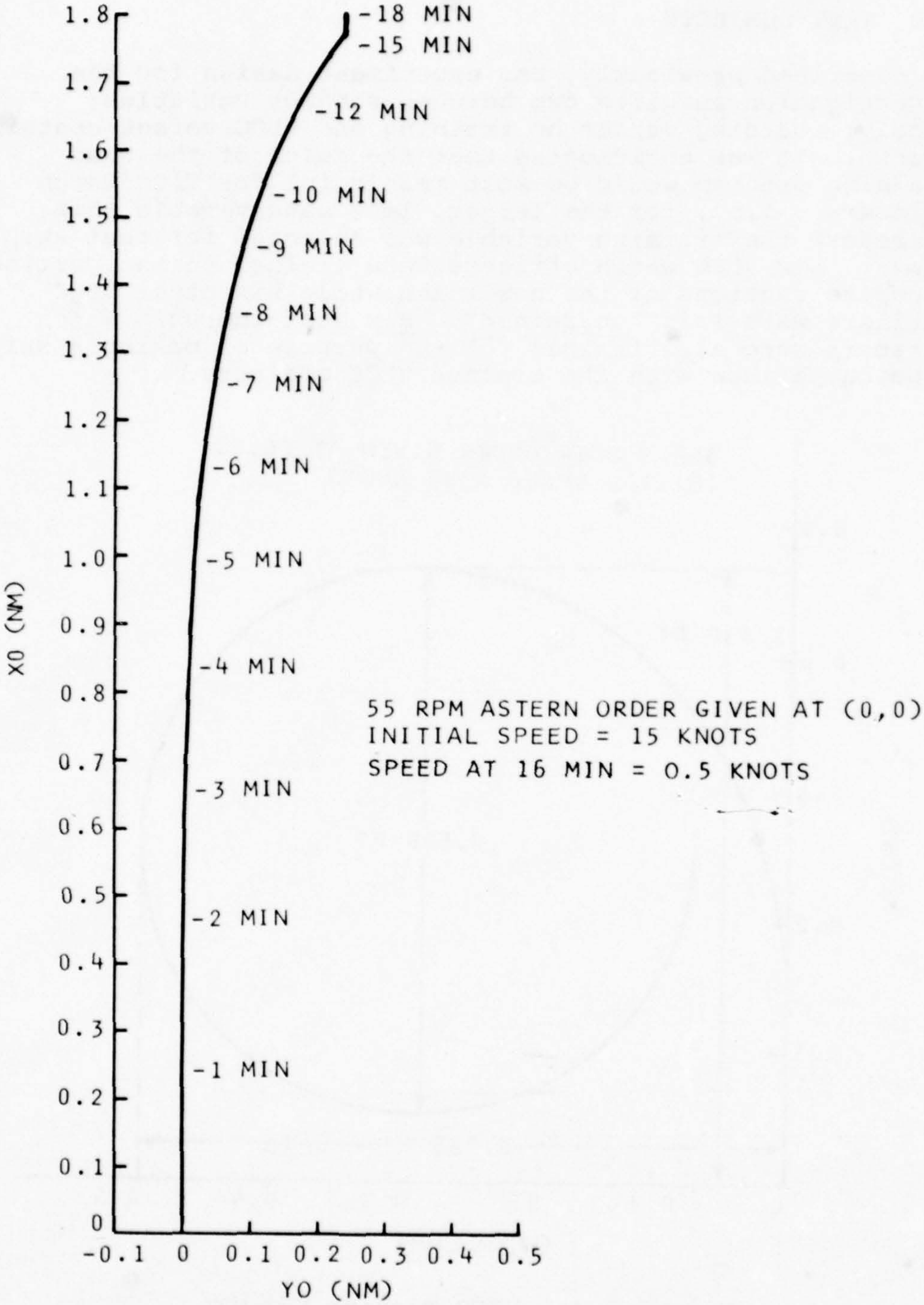


Figure 2-5. VLCC Crash Stop

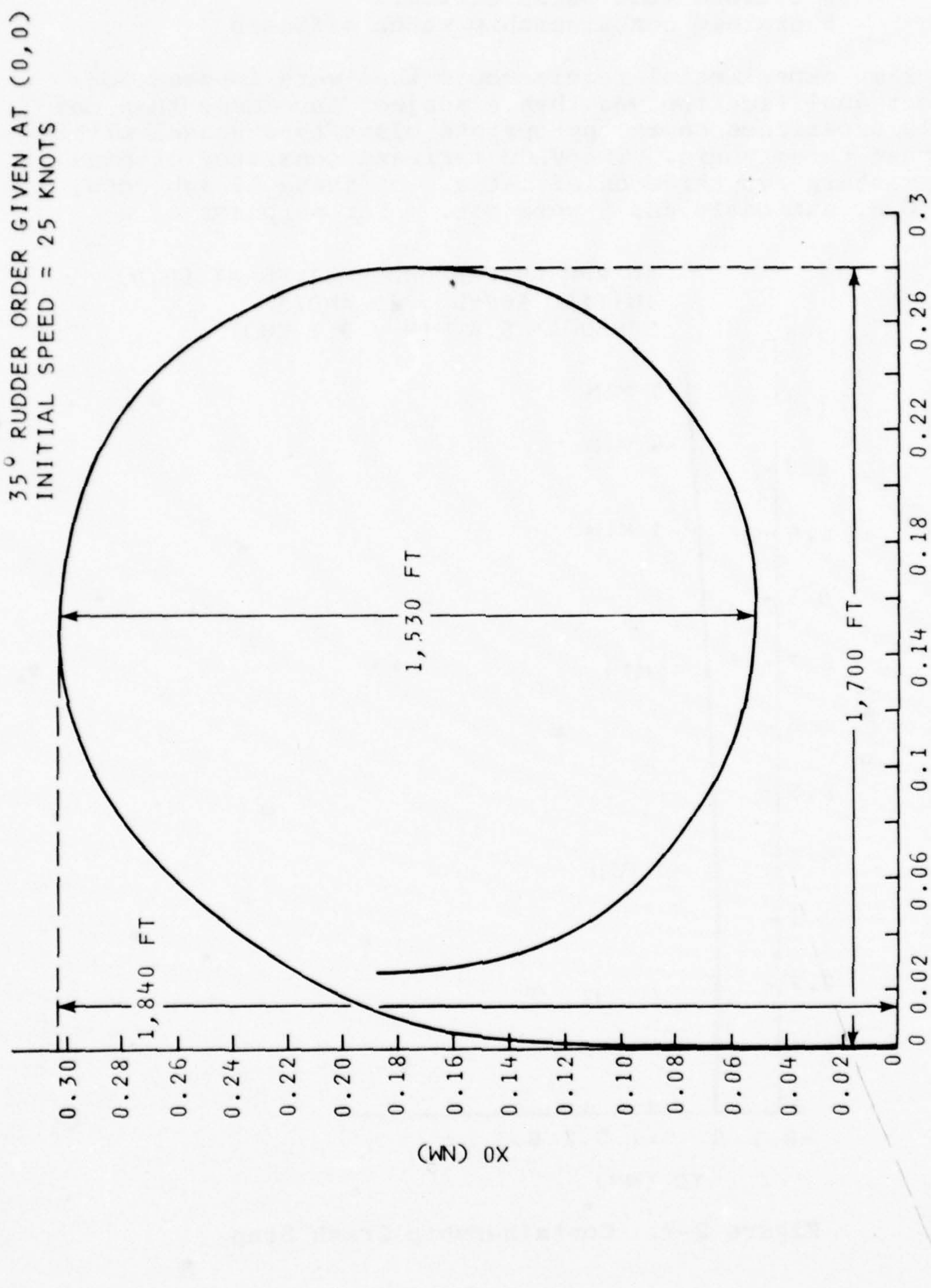


Figure 2-6. Containership Turning Circle

In all, 18 subjects were used for the experiment runs:

6 "untrained" VLCC watch officers
6 trained VLCC watch officers
6 trained containership watch officers

The prime experimental requirements that were imposed for subject qualification was that a subject have more than one year's experience on an appropriate class/type vessel within the past three years. The VLCC mariners consisted of nine ship masters and three chief mates. Of these 12 subjects, ‾ were U.S. nationals and 5 were not. For purposes of a

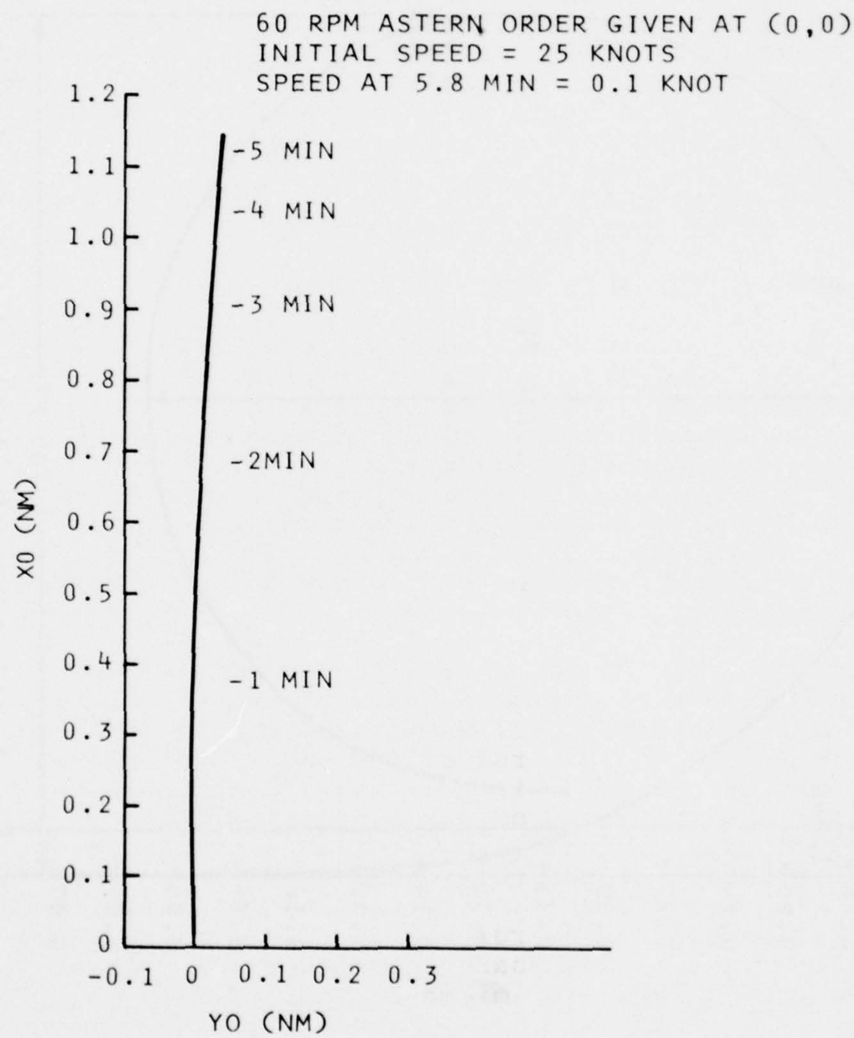


Figure 2-7. Containership Crash Stop

balanced design, these subjects were divided between the trained and untrained groupings such that three non-U.S. VLCC watch officers were trained and two were not. All six trained containership watch officers were masters and U.S. nationals.

It would have been undesirable to obtain the subjects from only one or two sources since uncontrolled biasing of the data could have resulted. It is felt that a fairly broad spectrum of subjects was obtained by the use of mariners currently employed by nine different companies, therefore getting a representative sample of the two classes of ship watch officers. Their backgrounds of age, experience, ship class, etc., are listed in Table 2-3. It should be noted that each subject was given a number (56 through 74) for identification purposes. In all cases, their test data and performance analyses were handled and filed by subject number, rather than name, in accordance with the standard CAORF procedure of test subject anonymity.

A description of test subject indoctrination and watch order instructions is included as Appendix F.

2.6 RULES OF THE ROAD TRAINING PROGRAM

The training program was developed to achieve several objectives: to impart a greater understanding of the Rules of the Road changes and their implications; to provide a context in which the subjects could make decisions under the new rules and, hence, develop a method of operation under the new rules; and to improve the consistency (i.e., predictability) of stand-on vessel actions via the new rules. In this regard, the training program provided an appreciation of the application of the new rules, their strong points and limitations.

The new Rules of the Road will stand on their own merits. Some amount of time, perhaps years of experience, may be necessary to acclimate all masters/mates to operations under the new rules. The adverse conditions of the transition period may be lessened via training. Hence, training with regard to the rule changes was a major variable of this research study. The training program attempted to provide an understanding of the rule changes and their implications, and assist each subject in familiarizing himself in making decisions under the new rules. In this manner, it was felt that the amount of necessary experience for consistent stand-on vessel behavior might be reduced.

TABLE 2-3

DECK OFFICERS' BACKGROUND

Subject Code	Ship Type	Age (Yrs)	Exp (Yrs)	Master/ Mate	Nationality
56	VLCC	53	24	Master	Non-U.S.
57	VLCC	39	18	Master	U.S.
58	VLCC	29	7	Mate	U.S.
59	VLCC	49	27	Master	Non-U.S.
60	C	49	27	Master	U.S.
61	C	52	32	Master	U.S.
62	C	54	10	Master	U.S.
63	C	53	30	Master	U.S.
64	VLCC	40	17	Master	Non-U.S.
65	VLCC	35	13	Mate	Non-U.S.
66	VLCC	50	26	Master	U.S.
67	VLCC	43	23	Master	Non-U.S.
68	VLCC	55	30	Mate	U.S.
69	C	53	17	Master	U.S.
70	C	45	25	Master	U.S.
71	VLCC	50+	33	Master	U.S.
72	VLCC	39	17	Master	U.S.
74	VLCC	50	15	Master	U.S.

The intent of the training program was not to interpret the rules, which is left for the courts. Rather, the intent of the program was to instill an awareness of the rule changes and the factors that affect their interpretation and application. The program addressed changes to the rules, particularly as they pertained to the new Rule 17 (i.e., actions of the stand-on vessel).

The training program took approximately three hours and was segmented into three parts: 1) identify rule changes; 2) discuss the areas of difference; and, 3) discuss implications of the new rule changes.

A total of six VLCC and six containership watch officers attended five training sessions that were held over a four-week period. Each session consisted of either two or three "trainees" with two of the sessions attended by mariners of one ship class and three sessions consisting of mixed ship classes. The same instructor/moderator was used for all five sessions in an attempt to maintain a consistency in the training received. The moderator was an experienced mariner and instructor of nautical science.

2.6.1 Sound-Slide Presentation

The changes to Rule 17 were presented by means of a sound-slide format and Table 2-4 lists all of the rule changes addressed and discussed by the training program. The sound-slide presentation took about three quarters of an hour to complete with a tape recording used for both the identification of the rule changes and the discussion of the areas of differences between the old and new rules. Each pertinent rule change was identified and followed by a brief discussion. The effect of the rule changes on the stand-on vessel was discussed in greater depth following the presentation of Rule 17 changes. This latter discussion, which concluded the sound-slide presentation, summarized the sequence of actions to be taken by the stand-on vessel.

Following the sound-slide presentation, which covered the parts of the Rules the experiment was most concerned with, a brief summation of the points addressed by the slides was discussed.

Four major points required clarification:

- Need to keep lookout with radar in all visibility conditions.
- Classification of not-under-command ships and the responsibility of each class.

- o Discussion of the head-on encounter rule.
- o Discussion of the stand-on ship's obligation.

1. Need to Keep Lookout

In this case, which covers several points in the new rules, it is important to appreciate that radar information and plotting is an essential means of establishing collision information in all visibility conditions-not just fog - and should be used as a means of deciding when collision risk exists.

TABLE 2-4

RULES ADDRESSED BY THE

RULES-OF-THE-ROAD TRAINING PROGRAM

Rule Number	Description
2	General Responsibility
3	General Definitions
5	Lookout
6	Safe Speed
7	Risk of Collision
8	Action to Avoid Collision
11	Application
14	Head-On Situation
15	Crossing
16	Action by Give-Way Vessel
17	Action by Stand-On Vessel
18	Responsibility Between Vessels

2. Classification

The new rules clearly define classes of ships which had previously been grouped together. Not-under-command ships as highest priority are ships which are incapacitated in some respect. Ships unable to maneuver because of their work, such as tug and tow, or ship lightening at sea are second priority and ships which are constrained by draft are third priority. In addition to these, there is need for a "stand-on" power-driven ship to keep out of the way of fishing vessels and sailing ships.

3. Head-on Case

To some extent the new regulations relax the rigid definition of head-on meeting and allow for the dubious (ambiguous) "end-on" case to be cleared by altering to starboard. In practice, before the new rules, it was not uncommon to find ships altering to port early in encounters which showed an 'end on' ship a few degrees on the port bow to make a safe green-to-green passage "before the rules became effective". The new rule suggests that in any case the ship must alter course to starboard if it believes itself to be in an end-on situation.

4. Stand-on Ship's Obligation

The important feature of this new rule is the relaxation of the commitment to hold on until the last safe moment before allowing the stand-on ship to contribute. The new rule defines that a threatened ship should, whenever possible, escape to starboard if the crossing ship does not maneuver in what the stand-on ship believes to be "good time." If however, the stand-on ship does not use her escape option and the situation deteriorates to a point where collision cannot be avoided by the action of the give-way ship alone, she is then still obliged to help out, as before.

2.6.2 Case Studies

The last portion of the training session was an in-depth discussion of the rule changes with regard to a variety of case studies. These were each presented as a one-on-one encounter with a series of radar plot diagrams used to describe the unfolding collision situation as a function of time. At each six-minute interval the plot was shown and a

fictitious watch officer's decision processes were described. It was the purpose of the case studies to draw out the "trainees" reactions to the stiuations and the correctness of the fictitious watch officer's actions based on the new rules and maneuvering characteristics of the vessels involved. In one case study the ownship (stand-on) might be a VLCC with the target (give-way) ship a containership. In another case study, the class of ships would be reversed. Both the VLCC and the containership "trainees" were required to discuss both ownship cases, to give them an appreciation of other vessels' characteristics. At least two case studies were used in each session. The purpose of the test cases was primarily to make sure that the subjects appreciated the new rules and their application. The discussions during the test cases also permitted an assessment of how the mariners had behaved in the past and whether they are going to be materially affected by the changes which have ocurred.

2.6.3 Pre-and Post-Experiment Tests

Pre-and post-experiment tests, investigating knowledge pertaining to the Rules of the Road, were administered to the trained groups. Only post-tests were administered to the no-training group. The pre-test assessed the entry level of knowledge possessed by the watch officers to be trained on the rule changes. This test was not given to the no-training group so as not to influence their experimental behavior regarding the new rules. The pre-tests also allowed evaluation of the effectiveness of the training program. The post-test was administered to all the mariners to assess their level of knowledge regarding the rule changes following their experience at CAORF. This test was administered to all masters immediately following completion of their second watch and also provided useful information concerning the untrained subjects' entry level of knowledge, as well as the benefits gained via CAORF experience in situations regarding the stand-on vessel.

The tests were constructed to assess the subjects' general level of knowledge pertaining to Rules of the Road, as well as their level of knowledge regarding the rule changes, with particular emphasis on Rule 17.

2.7 DATA COLLECTION

A variety of sources were used for data collection during the running of the experiment. The major performance measures were obtained from computer data logs and the Human Factors Monitoring Station data sheets, while subject-

ive data were obtained from debriefings, ground track plots as well as the Human Factors Monitoring Station data sheets.

2.7.1 Data Logs

The performance measures derived from the data logs, such as range to target ship at maneuver, CPA attained after maneuvers, and maximum course change after maneuvering, are available from the standard CAORF data recording system. These data were recorded on magnetic tape at a sampling rate of two sets of data per minute. The data logs also contain other problem parameters so that, for example, target ship position as a function of time as well as speed changes and rudder position were recorded for analysis when necessary.

2.7.2 Ground Track Plots

Subsequent to the completion of each watch segment, a computer-generated X-Y plot of ownship was provided from the basic playback tape recording. These plots were based on incremental positioning of ownship every two minutes. With the aid of an overlay containing other target ships' tracks, "quick look" data were available shortly after the completion of the run, and constituted one of the best overall assessments of the subject's performance. Included in Appendix C are reduced copies of the ground tracks and overlays for all subjects, which will assist in understanding the various traffic situations.

2.7.3 Human Factors Monitoring Station

The Human Factors Monitoring Station is the remote location from which bridge watch officer behavior may be observed unobtrusively. The monitoring station is provided with a closed circuit television presentation of all bridge activities as well as TV repeaters of the visual scene as viewed from the wheelhouse. The CAORF familiarization process ensures that the test subjects see and understand the functions of this station and that they concur with the experimental recording of audio and visual data. On the bridge itself, however, the cameras and audio pickups are unobtrusive and tend to be forgotten by the subjects during the simulation runs. The observer(s) at the Human Factors Monitoring Station manually recorded appropriate data using the Human Factors Monitoring Station data sheets, a time-annotated chronology of bridge activities. These data serve to support the results derived from the primary dependent variables and help in the understanding and explanation of bridge watch officer behavior with respect to threat assessment, problem

solving/decision making, and application of the Rules of the Road. They also yield key time indications for use with the voluminous data log printouts. These Monitoring Station data include the following:

- Range at maneuver
- CPA
- Radar behavior (e.g., changing range scale setting and erasing radar reflection plotting data)
- Changing engine order setting
- Activating ship's whistle
- Pelorus sighting for steady or changing relative bearing of targets
- Steering commands to helmsman
- Verbal requests for binocular information (target aspect)
- Attempts at voice communication (VHF) with target ship(s)
- Start and stop time (bridge time) of watch segment

In addition to real-time monitoring and manual recording of data, the observer at the Human Factors Monitoring Station recorded bridge video and audio, as required, for post-experiment playback and analysis. It is from this station that bridge personnel and Control Station operators were instructed by the experiment manager to initiate and terminate each watch segment, and the presentation of aspect information through the closed circuit TV binocular viewing system was controlled.

2.7.4 Debriefings

Each bridge watch officer was debriefed at the end of each scenario segment by a staff member who was the Human Factors Monitoring Station observer during the run. The primary objective of the debriefing was to elicit the information from each watch officer regarding how he interpreted the particular situation, his rationale for action (s) taken, and his interpretation of the Rules of the Road with respect to the given situation.

The debriefings were conducted outside of the CAORF wheelhouse. The Human Factors Monitoring Station observer asked generalized questions to elicit the sujects' reactions to the scenario, with follow-up questions to ascertain various reactions. The debriefings following each segment did not exceed ten minutes in duration. Watch officers' comments collected during each debriefing are included in the file data package for each subject. In addition to the "short" end of segment debriefings, a longer in-depth discussion was held with each of the subjects at the conclusion of his eight watch segments by a senior CAORF staff experimenter.

The short debriefings were held to obtain detailed information for each segment, as quickly as possible after the run, and every effort was made not to instill the debriefer's own concepts. The longer final debriefing could no longer affect the experiment results and a different class of questions and discussions resulted. Since no further runs were to be made by the debriefed subject, his subjective analyses could be obtained regarding the scenarios, chaff ships, use of radar, etc. A summary of the information obtained during these discussions form part of the results presented in paragraph 3.3.

CHAPTER 3

RESULTS AND DISCUSSIONS

3.1 INTRODUCTION

This investigation had two basic interrelated experiment designs: the first, a comparison between a trained group and an untrained group and the second, a comparison between ship classes - a VLCC group and a containership group. The statistical findings are presented for the training effect design in Section 3.2.1. The results of the ship type design are in Section 3.2.2. Section 3.4 has been entitled Generalized Considerations and is actually a catchall for other findings which do not fit concisely into the two previous sections. Results which are combined effects of both designs, such as restriction and crossing findings are found within 3.3. In addition, collisions, experimental uncertainties, and comments regarding subjective reactions of VLCC mariners in give-way vessel encounters are also found there. Conclusions and specific recommendations form the remainder of Section 3.

A series of appendices are included within this report and consist of scenario data and diagrams, definition of statistical terms used within the report, ground track plots of all experiment runs, and additional experiment data in both a raw and reduced form, as well as other experiment-related information.

3.1.1 Summary of Findings

An overall summary of the more prominent experiment findings is given below:

- o The change to the rules incorporated by means of Rule 17(a)(ii) did not disrupt the predictability of watch officer behavior; i.e., in an overwhelming majority of encounters, the stand-on vessel maneuver did not occur until the range to target ship was less than 5 nm.

- o Containership and VLCC watch officers maneuvered at similar ranges, but larger CPAs were attained by the containerships.

- o VLCC mariners were more constrained by their vessels' handling characteristics in the attainment of large CPAs, compared with containership mariners.

- o The VLCC group maneuvered with larger course changes in comparison with the containership group.

- o The containership group's performance was more standardized than that of the VLCC group; that is, they made fewer speed reductions and maneuvers to port than did the VLCC group.

- o The training program was effective in increasing the mariner's knowledge and understanding of the changes to the Rules of the Road, as shown by the increase between the test scores taken after training compared with the test scores obtained prior to training.

- o A transfer of training to behavior on the simulator was established since:

  a. More consistent performance in terms of range to threat vessel at maneuver (smaller average standard deviation) was exhibited by trained subjects than by untrained subjects.

  b. Larger course changes and a smaller number of course changes per maneuver were made by the trained subjects than by the untrained subjects.

- o Restrictions on the right for VLCC mariners resulted in increased non-standard behavior (maneuvers to port or speed changes) compared to non-restricted situations.

- o Restrictions on the right resulted in range to threat vessel at maneuver being greater for VLCC mariners compared to non-restricted situations.

- o Restrictions on the right caused by oil rigs affected VLCC mariners more than restrictions due to shoal water.

- o Trained subjects maneuvered at greater range to threat vessels under ambiguous crossing conditions compared to the clear-cut crossing encounter, thereby, taking greater advantage of the allowances of rule 14-C.

3.1.2 Overview

3.1.2.1 Range at Maneuver

Many authorities feared that the changes to the Rules of the Road could result in situations in which stand-on vessel watch officers would use the latitude of Rule 17(a)(ii) as authority to maneuver arbitrarily (i.e., at any time that they might wish), resulting in completely unpredictable behavior and destruction of the stand-on vessel concept. This experiment attempted to assess the behavior of VLCC and containership watch officers in fine crossing situations, while operating under the new rules and, in part, to confirm (or allay) these fears.

The probability of a stand-on vessel maneuver as a function of range to the give-way vessel was calculated from the collected experiment data in order to investigate differences in the probability of maneuver due to the effects of training and/or ship types and provide important information relating to the likely behavior of the stand-on vessel in the situations under investigation.

The probability of maneuver is plotted for all data (VLCC and containership) in Figure 3-1. As can be seen, the curve has the classic ogive pattern denoting the cumulative of a normal distribution. This curve shows that in about 10 percent of the cases the stand-on vessels had maneuvered by a range of slightly more than 6 nm; in about 50 percent of the cases the stand-on vessels had maneuvered by a range of 4 nm; and in 90 percent of the cases had maneuvered by a range of 2-1/2 nm. The mean range for all subjects for all runs was 4.04 nm, with a standard deviation of 1.51 nm.

Comparisons between the training and no-training groups, and ship type groups are plotted in Figures 3-2 and 3-3. Inspection of these curves shows that no real differences appear to exist between the different treatments. The probability of maneuver appears to be more dependent on range than on ship type or training.

At the conclusion of the background discussion in Section 1.4 of this report, it was stated that as a result of a literature search, the most "accepted" value for ownship to maneuver from a stand-on vessel position, as a consequence of new Rule 17(a)(ii), is between 2.0 and 4.5 nm. This "value" recognizes the variabilities due to encounters, ship types, speeds, etc. One source, Church (1974), reported that courts might interpret the outer limit of a permissible maneuver at 5 miles. The findings from this experiment show

that, in more than 90 percent of the cases, the stand-on vessels maneuvered at a range greater than 2.3 nm with 25 percent of the maneuvers greater than the 5 nm point.

The experiment results show that about one-third of the subjects maneuvered prior to the 4.5 nm range "approved" in the literature. On the other hand, by far the largest portion of them (approximately three-fourths) desired and attained their maneuvering range within the "projected court interpretation" of 5 nm.

The results of these data, therefore, indicated all watch officers maneuvered at approximately the same average range (4 nm), independent of type of ship or training, and that 75 percent of them waited until at least 5 nm to execute their escape maneuver. Since this occurred on vessels which had stand-on responsibility, it appears that the initial fears that were expressed regarding predictability of maneuvering range were not substantiated. Watch officers did not maneuver arbitrarily and an extrapolation of the experiment findings indicates that stand-on/give-way vessel responsibilities will be maintained.

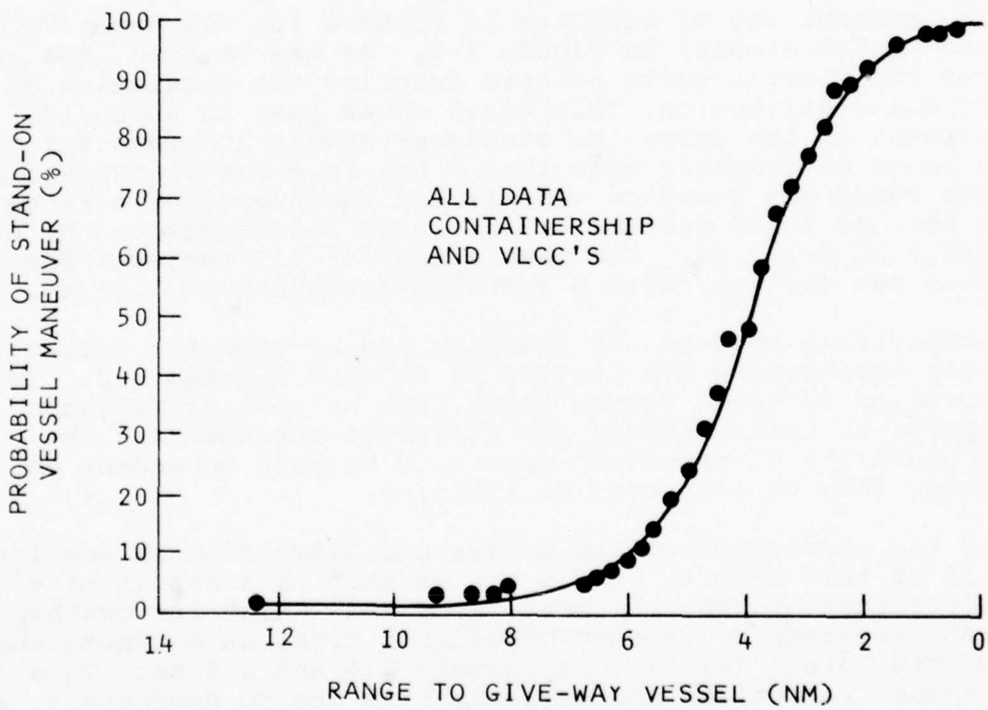


Figure 3-1. Cumulative Distribution of Range at Maneuver - All Subjects

Another consequence of these same findings, the similarity of maneuvering range between mariners controlling vessels with grossly different ship handling characteristics, is discussed in the following paragraph concerning attained CPAs.

Figure 3-4 is a plot of actual mean range versus desired range for 15 of the 18 subjects. As indicated previously, the desired ranges were obtained during the training program and/or the final debriefings. (The desired ranges were not specified by three of the VLCC watch officers.) It should be noted from Figure 3-4 that in approximately 60 percent of the cases, test subjects maneuvered at ranges equal to or greater than the ranges that they indicated they desired and approximately 15 percent indicated a desire to maneuver at a range greater than 5 nm.

The information provided by the curves of Figures 3-1, 3-2, and 3-3 will also be useful in the design of future experiments at CAORF and other simulation facilities. An example is the selection of maneuver ranges for the chaff targets in the current experiment. A maneuver range of about 5 to 6 1/2 nm was selected based on the implications of the

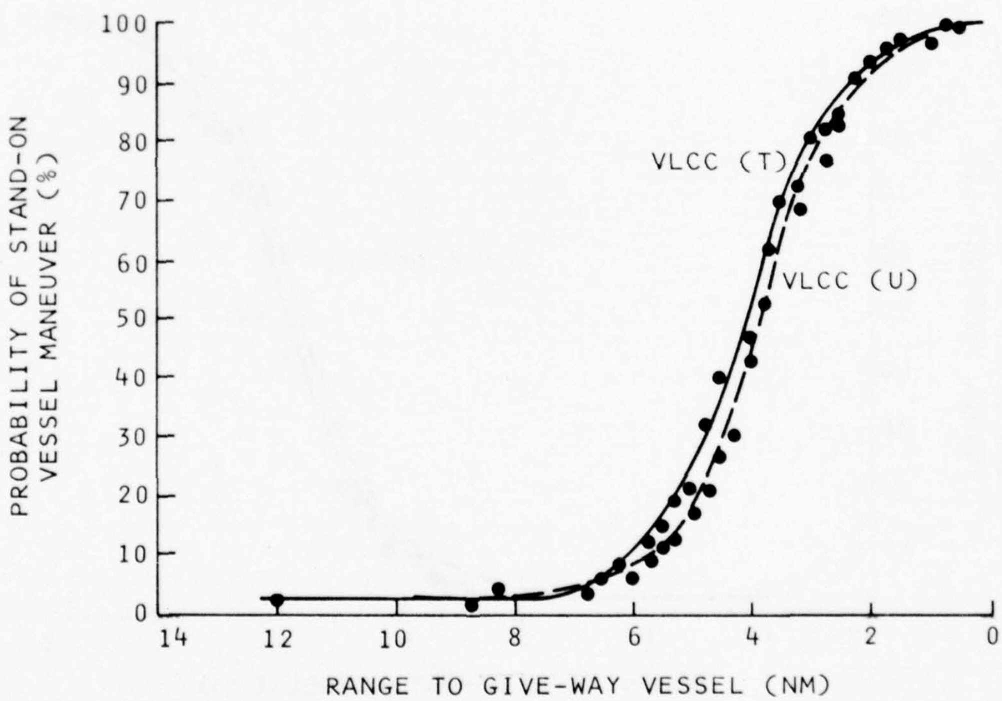


Figure 3-2. Cumulative Distribution of Range at Maneuver- VLCC (Trained and Untrained)

researched literature. It was hoped that this range would result in a small number of maneuvers for chaff ships. This, in fact, occurred. The probability curve further substantiates this conclusion, showing about 10 percent maneuvered at or before 6 nm.

3.1.2.2 Resultant Attained CPA to Primary Threat Vessel

In a manner similar to the performance measure of range, the attained CPA data were collected and used to generate a series of probability curves. The attained CPAs have been plotted for all subjects (VLCC and containership) and are presented in Figure 3-5. The overall mean CPA for all subjects, on all runs, was 0.59 nm with a standard deviation of 0.33 nm.

The differences between subject groupings will be discussed under the appropriate independent variables, i.e., training (VLCC-trained versus VLCC-untrained) and ship type (VLCC-trained versus containership-trained), and these relationships are graphically shown in Figures 3-6 and 3-7. A significant difference in attained CPA has been indicated

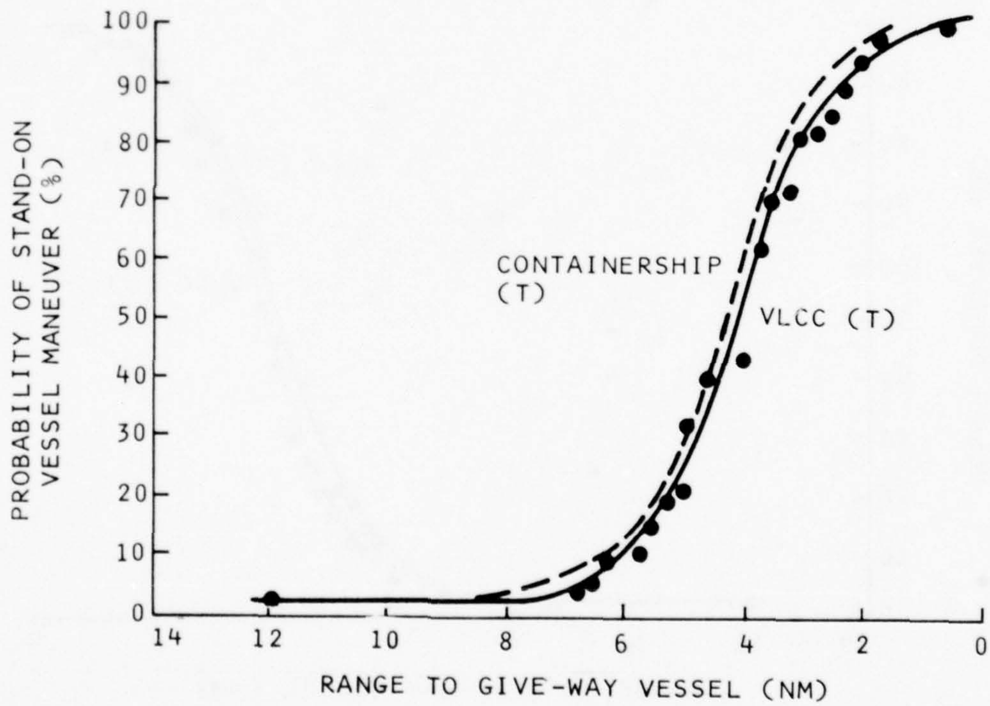


Figure 3-3. Cumulative Distribution of Range at Maneuver- VLCC (Trained) and Containership (Trained)

for the comparison of V_T and C_T (ship type), with the VLCC trained group attaining a mean of 0.54 nm and the containership trained group attaining a mean of 0.82 nm, which is more that 50 percent higher. The VLCC untrained group had a mean of 0.42 nm.

One of the interesting, and one might even say dramatic, findings which resulted from the investigation can be seen in the lower ranges of the CPA probability curves (Figures

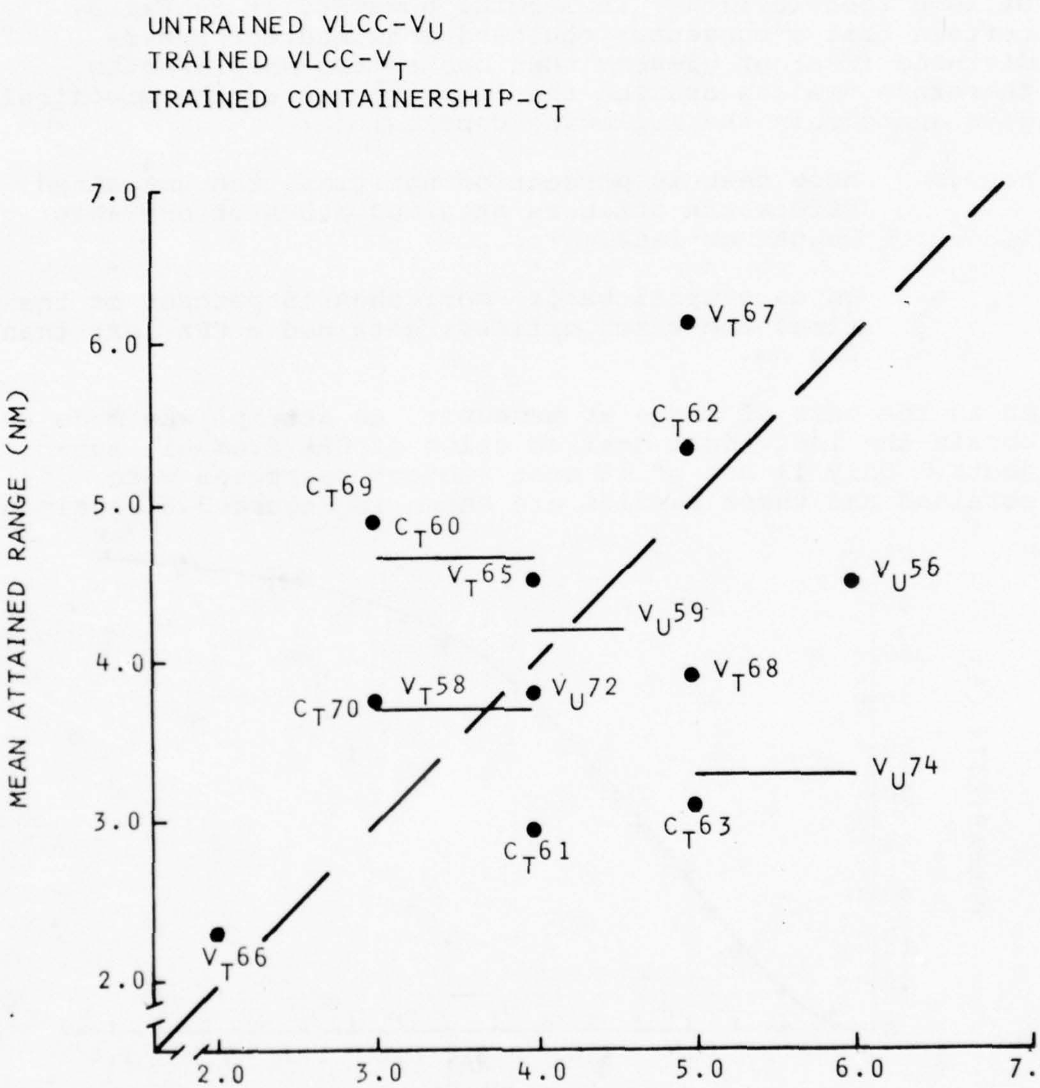


Figure 3-4. Mean Range to Target at Maneuver vs Desired Range

3-5, 3-6, and 3-7). These curves are based on the total experiment runs. In typical ogival manner, they represent the percentage of times the attained CPA was less than a given distance, and by extrapolation this can be thought of as the probability of encounters under at-sea conditions with a given CPA. The literature that has been reviewed in concert with this investigation has not indicated any recommendations for attained CPA, since this appears to be an extremely subjective area which is heavily dependent on an individual mariner's experience. When discussing ships of 1000 feet (0.17 nm) in length, however, it is fairly certain that a consensus could be obtained for a miss distance (CPA) of greater than one to two ship lengths. Therefore, we can examine the lower ranges of the graphical data and obtain the following conclusions:

- More than 10 percent of the time, the untrained VLCC watch officers attained a CPA of one ship length or less.

- On an overall basis, more than 15 percent of the time, the watch officers attained a CPA less than 0.3 nm.

As in the case of range at maneuver, an attempt was made to obtain the individual desired value of CPA from all subjects. Only 11 out of 18 test subject responses were obtained and these results are shown in Figure 3-8, again as

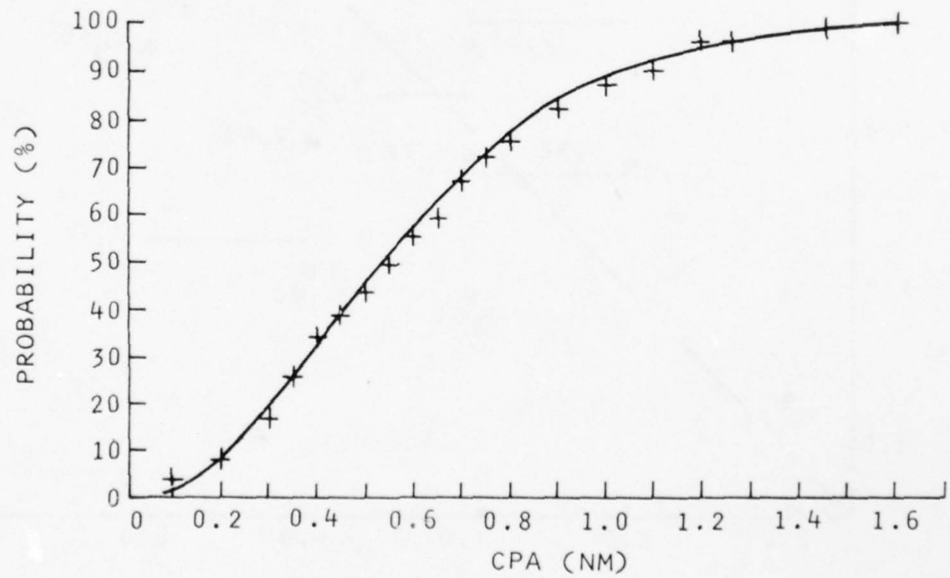


Figure 3-5. CPA Cumulative Probability - All Subjects

a plot of desired versus attained CPAs. The plotted data shows that almost every watch officer attained a CPA which was less than he had indicated that he wanted. More than 70 percent had indicated that they wanted a CPA of 1 nm or more, yet less than 15 percent (85 percent point on Figure 3-5) attained that goal. It is not possible to ascribe this discrepancy to a possible difference between simulated and actual ship handling characteristics for the following reason. All subjects were questioned, subsequent to their experiment runs, regarding the "feel" of the CAORF simulator, be it VLCC or containership and, except for minor comments to the contrary, in almost all cases the universal subjective reaction was that the CAORF handling characteristics were realistic and that the simulator "handled well". It should be emphasized that this information was collected from the subjects after they had seen the closeness of their attained CPA results in the experiment runs on the simulator.

An explanation to account for the discrepancy must, therefore, lie elsewhere. In an attempt to discover a possible reason for both the differences between attained and desired CPA performances and the strikingly small values of attained CPAs for the VLCC groups, a series of analyses were performed subsequent to the experiment runs to determine the CPAs that could effectively be realized by both the VLCC and containership vessels.

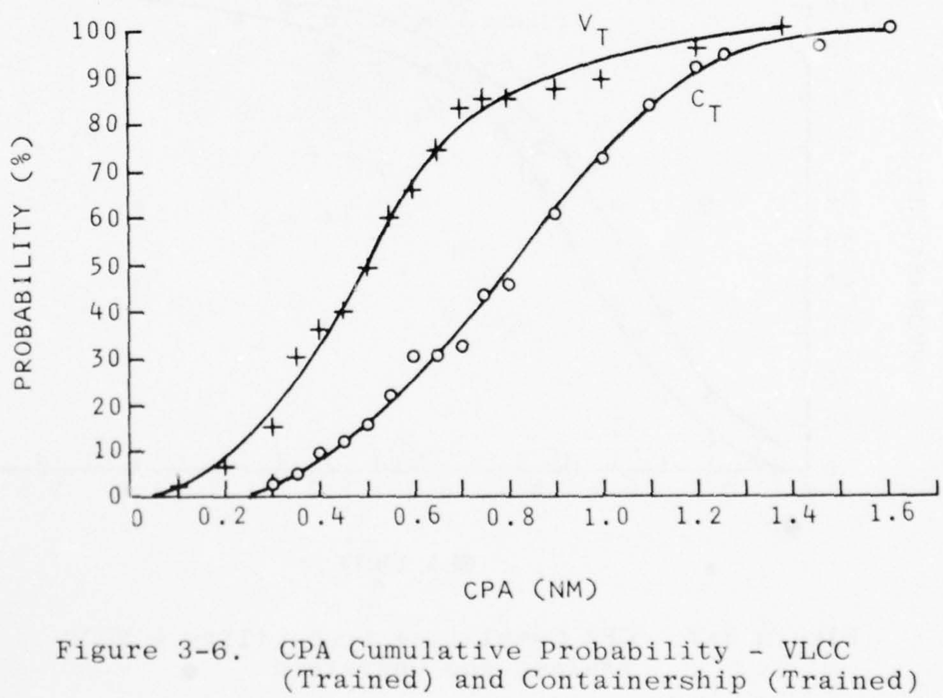


Figure 3-6. CPA Cumulative Probability - VLCC (Trained) and Containership (Trained)

The results of these analyses are shown in Table and indicate the CPAs that can be attained with either vessel for a series of efficient course changes and two reciprocal course angles, 5° and 25°, when proceeding at speeds comparable to those in the experiment runs. An efficient course change is one that is initiated with a large rudder angle, resulting in the most rapid build-up to the maximum practical turning rate and then "steadying up" on the new course, with a minimum of overshoots. The reciprocal course angles of 5° and 25° are approximately the crossing angles used for the encounter geometries of ambiguous crossing and clear-cut crossing, respectively. The tabulated results are for standard maneuvers (turns to starboard) which are executed at a range to threat vessel of 4 nm (the average range for all subject groupings) and a 40-knot closing rate. The results indicate the best CPA that watch officers could attain for a given set of parameters; degradation from these values will occur when the maneuver is not made efficiently, or made in a series of course changes, or when the ship is not held on the changed course until the CPA has been attained, etc. The results show that the potential CPA available to a containership mariner (maneuvering at 4 nm) varies between 1 and 3 nm dependent on the parameters involved, which in turn indicates that the master of the more maneuverable vessel could have achieved practically any CPA that he desired. The potential CPA available to containership mariners at a 4 nm maneuver range is large

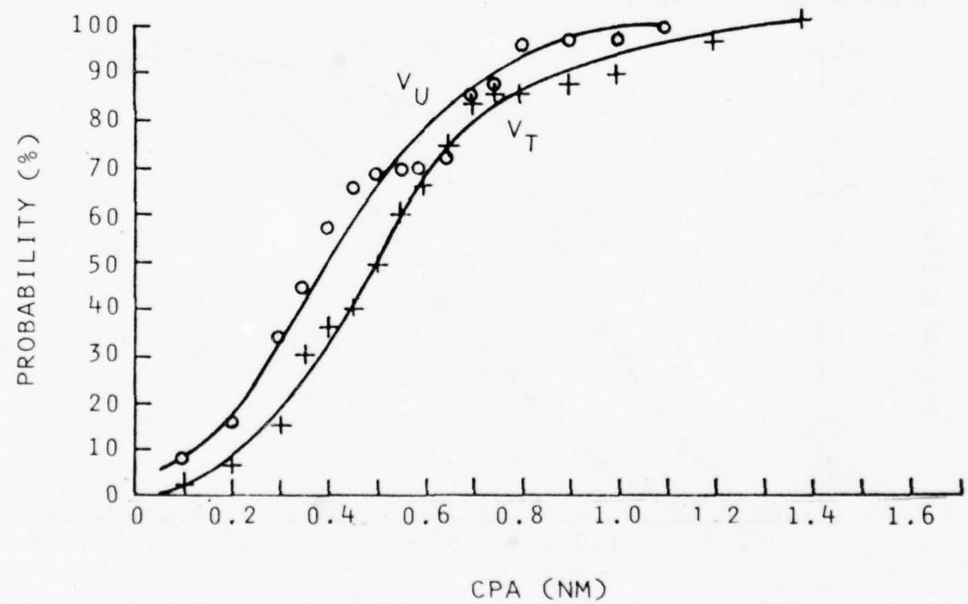
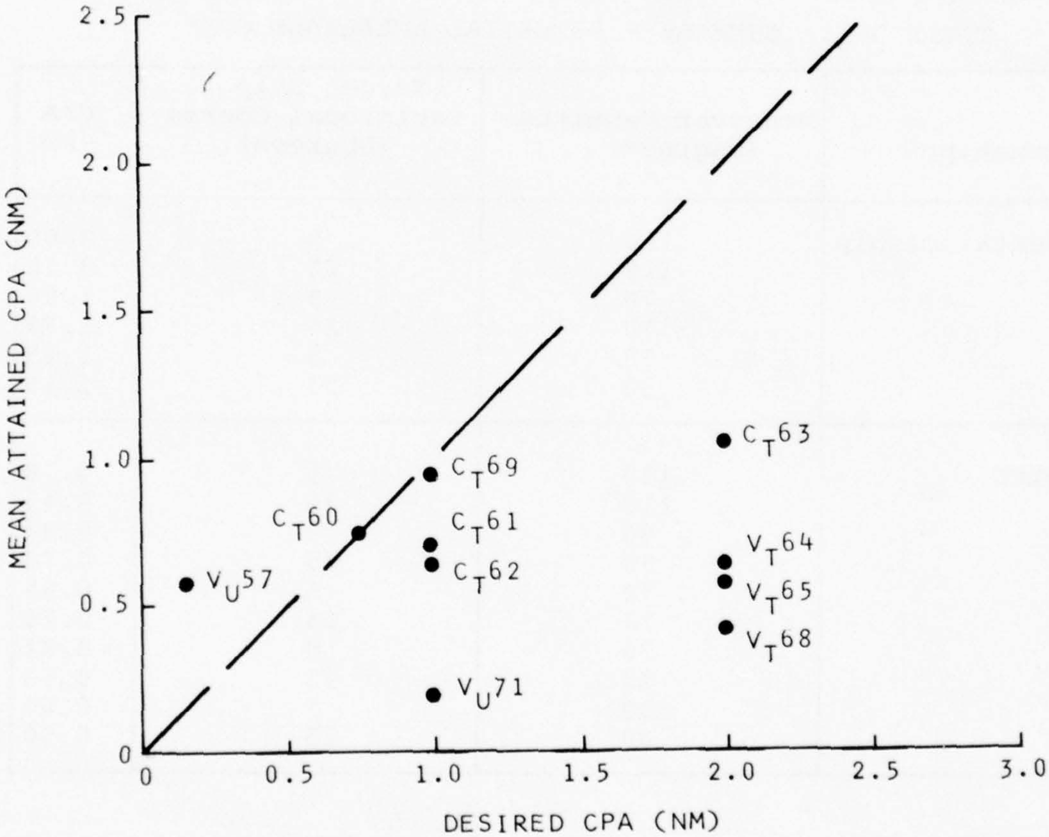


Figure 3-7. CPA Cumulative Probability - VLCC Trained and Untrained

because of the turning and speed characteristics of their vessels and they, therefore, have a large reserve CPA when, and if, they delay slightly with their maneuver or do not maneuver efficiently.

The results for the VLCC man/ship combination show a striking contrast, however. When the maneuver is initiated at 4 nm, the potential CPA varies between 0.95 and 0.50 nm with the larger CPA resulting from the extensive 70° or 90° course changes. The potential CPAs available to the VLCC mariner are smaller than those of the containership and, with degradation from these values, it is apparent that the reserve CPA for the VLCC man/ship combination could become dangerously small.

Herein lies the reason for the apparent discrepancies noted earlier; the differences between attained and desired CPAs for the VLCC and the low values of attained CPAs for VLCC



Fgiure 3-8. Attained CPA vs Desired CPA

vessels. Table 3-1 is a quantification of the difference between a fast maneuverable vessel and one that is slower and more ponderous in potential collision situations for crossing and crossing/meeting stand-on encounters. Figures 3-9 and 3-10 indicate the aforementioned data in another way. Each contains the optimum CPA that can be obtained with efficient maneuvering at various maneuver magnitudes and crossing angles for a class of ship. Also shown, in circles, are the desired CPAs that had been indicated by each subject (see Figure 3-8), plotted as a function of the average maneuver magnitude that was attained by each during his experiment runs. In addition the average attained CPA and average maneuver magnitude for all subjects in each ship class are shown within the squares. The scatter diagram (Figure 3-8) shows that desired CPAs for the containership mariners are bunched near the actual results while the desired CPAs of the VLCC mariners are generally far from the

TABLE 3-1. SUMMARY - POTENTIAL AVAILABLE CPA*

Ownship	Maneuver Magnitude (Degrees)	Target Ship Reciprocal Course (Degrees)	CPA (NM)
Containership	110	5	3.00
	110	25	3.10
	70	5	1.98
	70	25	1.79
	30	5	1.15
	30	25	1.15
VLCC	110	5	0.78
	110	25	0.45
	90	5	0.95
	90	25	0.70
	70	5	0.95
	70	25	0.75
	50	5	0.81
	50	25	0.63
	30	5	0.60
	30	25	0.50

* Maneuver - to starboard at 4 NM to threat vessel

actual values and in most cases are even well beyond the capability of their vessel. All of these data are based on a maneuvering range of 4 nm. To determine the full impact of these findings, further graphical analyses were performed for a spread of ranges at maneuver using the VLCC as the stand-on vessel. The results are shown in Figure 3-11 and indicate that, for the fine crossing encounters of 5 and 25 degrees, a VLCC at 15 knots requires 8 miles to achieve the desired 2 mile CPA, using a maneuver magnitude of 55 degrees. It will be recalled that 55 degrees was the experimental mean for the VLCC trained group. (The value for the no-training VLCC group was even smaller, i.e., 40 degrees.) Since these curves represent the optimal potential CPAs that are available, and recognizing that attained CPAs are always a fraction of these values (conservatively, say 3/4), then even a 1 nm CPA can be attained, with a VLCC vessel using a 55° maneuver only when the range at maneuver is greater than

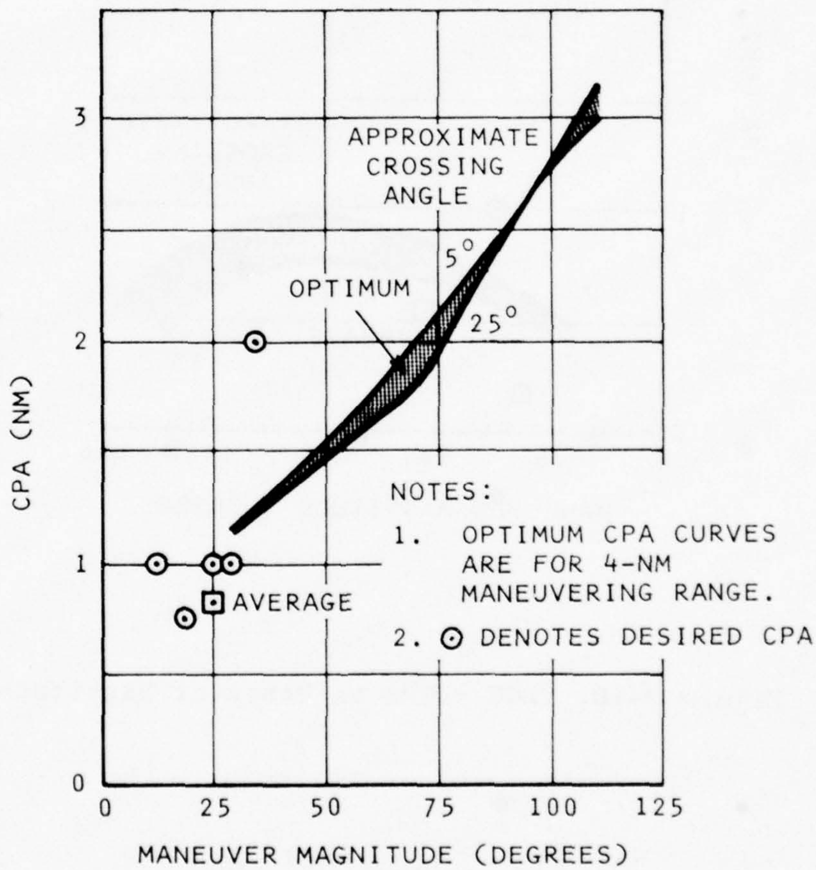


Figure 3-9. Containership - CPA vs Maneuver Magnitude

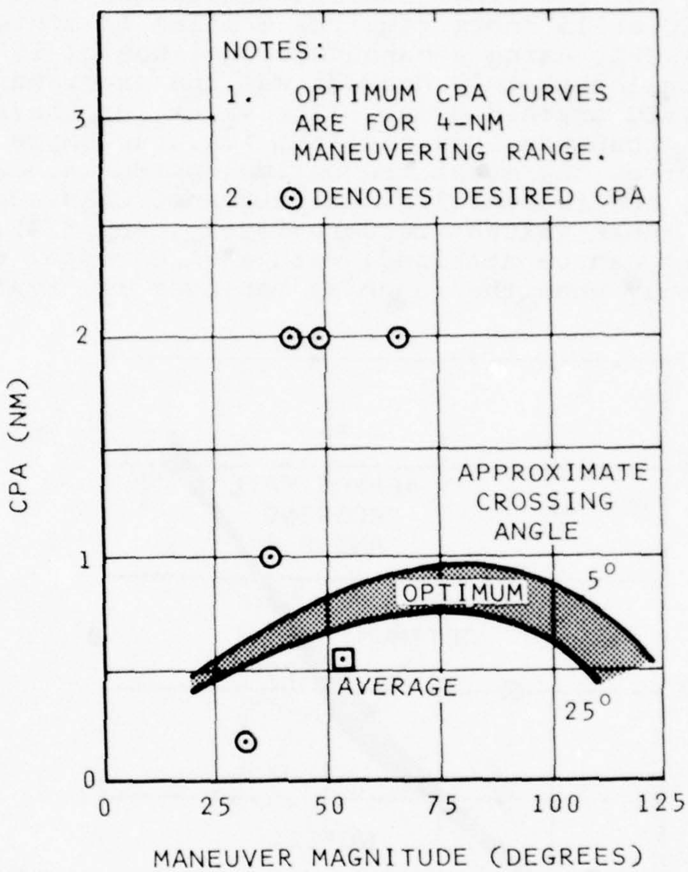


Figure 3-10. VLCC - CPA vs Maneuver Magnitude

6 miles. These analyses bring up an interesting question: "Why did the mariners for the two classes of vessels maneuver at approximately the same range?" This will be addressed later in the report in the ship type design.

3.2 DUAL EXPERIMENT DESIGN

3.2.1 Training Effect

The Rules of the Road training program was a non-simulator, classroom course designed to address those changes to the international rules that pertain to a collision situation in daylight. Table 2-4 listed those rules addressed by the program. Particular emphasis was placed on Rule 17 (Action by the Stand-On Vessel), which represents the major change to the rules. The intent of the course, however, was to adequately address all the relevant changes.

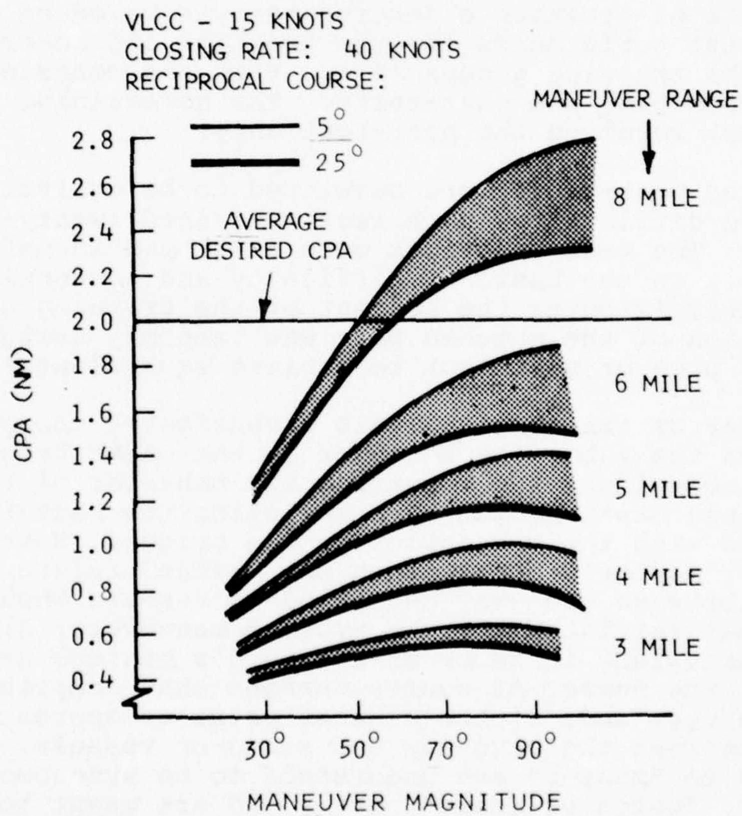


Figure 3-11. VLCC CPA vs Maneuver Magnitude at Different Maneuver Ranges

The specific objectives of the Rules of the Road training program were threefold: 1) to give the trained test subjects a greater understanding of the rules and rule changes; 2) to achieve an increased capability by the masters to operate under the new rules; and, 3) to improve the consistency of maneuvering by the masters. The third training objective was developed in response to the concept that the new rules might result in less predictable behavior by the stand-on vessel. That is, the old rules placed a greater constraint on the stand-on vessel's actions than the new rules. Hence, masters could be less consistent in the ranges at which they maneuver the stand-on vessel under the new rules. The third objective of the training program was developed to offset this possible tendency.

The analysis of the results of the training program followed a dual approach: 1) investigation of the effectiveness of the training program; and 2) investigation of the transfer of training to the masters' behavior on the CAORF bridge. The analysis of training effectiveness was based on pre-test and post-test performance for the training and no-training groups. The training groups (i.e., VLCC and containership) received both pre- and post-tests. The no-training group (i.e., VLCC) received the post-test only.

The pre- and post-tests were developed to be equivalent in content and difficulty. Each test contained twenty-eight questions. The test questions were developed in matched pairs (i.e., on the basis of difficulty and content) to representatively cover the content of the training program. Each question of the matched pair was randomly assigned to either the pre- or post-test to achieve equivalent tests.

The transfer of training analysis investigated the effect of training on the subject's behavior on the CAORF bridge. This was accomplished by comparing the behavior of trained and untrained masters, and by correlating the master's test performance with their behavior on the bridge. Note that the phrase "master's behavior on the bridge" refers to: 1) the range between give-way and stand-on vessels when the maneuver was initiated; 2) the type of maneuver,; 3) the maneuver magnitude in terms of the ship's maximum heading change; 4) the number of course changes that comprised the total maneuver; and, 5) the closest point of approach (CPA) achieved between the give-way and stand-on vessels. Also, references to "master" are understood to be synonomous with "subjects", "watch officers", etc., and are meant to include those subjects that were actually chief mates.

3.2.1.1 Training Effectiveness

The effectiveness of the Rules of the Road training program is an issue that is independent of the experiment runs on the CAORF bridge. This investigation was based on the pre- and post-experiment test performance of the training and no-training groups. It evaluated the effectiveness of the training program in terms of the master's differential understanding of the new Rules of the Road as a result of having participated in this training program.

The pre- and post-experiment test scores are summarized for the three groups (i.e., VLCC - no-training; VLCC - training; containership - training) in Table 3-2. Inspection of this table reveals that the pre-experiment test scores ranged from a low of 11 to a high of 22. Although the highest pre-test scores were somewhat different for the training VLCC and containership groups, the means were not significantly different.

TABLE 3-2

PRE- AND POST-EXPERIMENT TEST

PERFORMANCE SUMMARY

Test	Group	Range of Scores	Average Scores	Score Standard Deviation
Pre	Training VLCC	11-22	15.33	4.3
	Containership	12-17	14.50	1.87
Post	Training VLCC	10-25	17.83	5.34
	Containership	14-23	19.33	3.01
	No-Training VLCC	10-17	13.0	2.76

The means of the post-test scores for the trained VLCC and containership groups were likewise not significantly different; their range of scores differed somewhat on the low end. Comparison of the standard deviations between these groups, of both the pre- and post-experiment tests, show greater variance for the VLCC group. This may be due to the VLCC-training group's composition of three U. S. masters and three foreign masters.

The mean and range of scores on the post-experiment test for the VLCC (no-training) group were lower than those of the other two groups. The standard deviation was about the same as that of the containership group.

The effectiveness of the training program may be measured in two ways: 1) Comparison of pre- and post-experiment test scores; and, 2) comparison of post-test scores for the training and no-training groups.

The post-experiment test appears to have been more difficult than the pre-experiment test. This conclusion was reached by a comparison of the mean pre-experiment test scores for the trained groups with the mean post-test score for the no-training (VLCC) group (see Figure 3-12). The pre-experiment test score was expected to be lower than the no-training group's post-experiment test score, since the latter test was administered after those masters had participated in the experiment runs and the runs might be expected to affect the post-experiment test score. The obtained lower post-test score, converse to what was expected, therefore indicates that the post-test was more difficult than the pre-test.

3.2.1.1.1 Pre- versus Post-Test

The training program's effectiveness, measured by difference between pre- and post-test scores, is shown by the analysis of variance comparison summarized in Table 3-3. The post-test performance of the containership group was found to be significantly better than their pre-test ($p < 0.05$). The performance increase of the VLCC group was not found to be significant. This lack of significance is due to the wide variance in the scores of both the pre- and post-tests for this group.

The second method of evaluating the training effectiveness is a comparison of the training and no-training groups' performance on the same test, the post-test. The analysis for these results is summarized in Table 3-4. The overall comparison shows a 43 percent higher post-test score for the trained groups, which was significant ($p < 0.01$). This

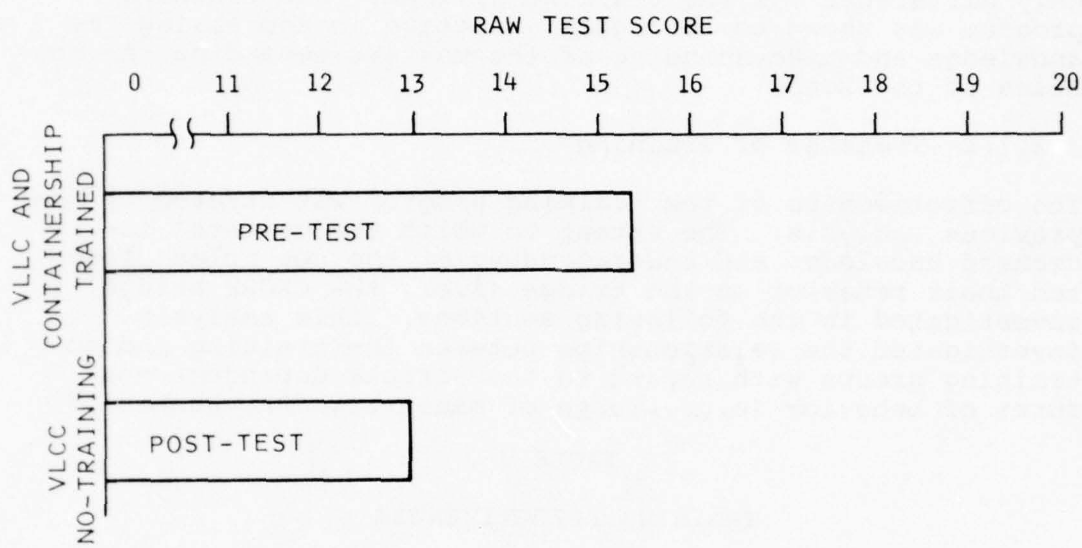


Figure 3-12. Overall Pre-Test vs Post-Test Scores

finding was further substantiated by the 37 percent higher post-test score for the VLCC (training) group, which was also significant (p <0.06).

The above findings demonstrate a significant in the watch officers' knowledge and understanding of the new Rules of the Road as a result of the training program. The pre- and post-test comparisons provided a direct estimate of the increase for individuals. The comparison of performance on the post-test further substantiates these conclusions; the post-test provided a comparison between groups, in which the only difference was the training program. The training program was shown to be highly effective in increasing the knowledge and understanding of the masters regarding the new Rules of the Road.

3.2.1.2 Transfer of Training

The effectiveness of the training program was strated by the previous analysis. The extent to which the masters' increased knowledge and understanding of the new rules affected their behavior on the bridge (i.e., the CAORF bridge) is investigated in the following sections. This analysis investigated the relationships between the training and no-training groups with regard to the various dependent measures of behavior (e.g., range of maneuver, CPA, number of

TABLE 3-3

TRAINING EFFECTIVENESS -

COMPARISON OF PRE- AND POST-TEST PERFORMANCE

Group	Mean Scores	
	Pre-Test	Post-Test
Containership & VLCC	15.40	18.58*
Containership	14.50	19.33**
VLCC	16.33	17.83

*$p < 0.05$ ($F = 7.9$; $d_f = 1,11$) Analysis of Variance

**$p < 0.05$ ($F = 14.36$; $d_f = 1,5$) Analysis of Variance

non-right maneuvers). Additional analysis compared post-test performance with the various dependent measures of behavior. A variety of statistical techniques were employed to ascertain the significance of the findings. The analyses and findings are presented below.

3.2.1.2.1 Consistency of Behavior

A major objective of the training program was to increase the consistency of the master's behavior when his ship is the stand-on vessel, thus counteracting the tendency that the new rules might have to produce less predictable behavior. In particular, the training program sought to encourage mariners to completely assess the situation and to maneuver at a range consistent with their assessment of the situation and interpretation of the rules. Hence, a higher degree of consistency would be achieved if the masters

TABLE 3-4

TRAINING EFFECTIVENESS -

COMPARISON OF TEST SCORES OF TRAINING AND

NO-TRAINING GROUPS

Groups	Mean Test Scores	
VLCC (No-Training)(Post-Test)	13.00	
versus		**
Containership & VLCC (Training)(Post-Test)	18.58	
VLCC (No-Training)(Post-Test)	13.00	
versus		*
VLCC (Training)(Post-Test)	17.83	

*$p < 0.06$ ($F = 6.32$; $d_f = 1,5$) Analysis of Variance

**$p < 0.01$ ($U = 8$; $d_f = 5,11$) Mann-Whitney

always maneuvered at a similar range in similar situations. The situations investigated in this experiment were generally similar when compared with the variety of possible situations. The experimental situations that were investigated involved two ships and were all relatively fine crossing situations with a relatively high closing rate of greater than 35 knots.

The range between the stand-on and give-way vessels when the stand-on vessel's escape maneuver under Rule 17(a)(ii) was initiated, was considered the primary parameter relating to the master's behavior. No attempt was made in the training program to influence the range at which maneuvers were initiated. The training program did, however, attempt to increase the master's consistency in determining the range at which to maneuver. The investigation of range consistency was based on the range standard deviation for each master. The standard deviation of the distribution of the range at maneuver for each subject's runs was computed and the mean (average) of these standard deviations for the training and no-training groups was calculated.

The trained groups consistently achieved significantly smaller means of standard deviations of range than the no-training group. The VLCC training group had a factored* mean range standard deviation of 1.0 nm compared with 1.39 nm for the VLCC no-training group. Similar results were obtained when comparing containership (training) (0.69 nm) to VLCC (training) (1.0 nm). These results demonstrate a link between the training program and behavior on the CAORF bridge. The masters who participated in the training program demonstrated a greater consistency in the range at which they initiated the stand-on vessel's maneuver. Comparisons between the groups are illustrated in the three plots of Figure 3-13. The summary of the statistical results for these comparisons is presented in Table 3-5.

The increase in knowledge and understanding of the new rules gained by mariners in the training groups is likely to have varied widely due to individual differences in the rate and style of learning. The previous comparisons between pre- and post-test scores substantiate this assumption. Additional variance in the training and no-training groups was likely to have been contributed by the input level of each master's knowledge and understanding of the new rules, which may vary considerably. The post-test, which was also

*Note: The results for one trained VLCC subject's standard deviation (Subject #67) were factored to adjust for the spurious findings (12.19 nm maneuvering range) for the B4 run; see Table D-1 in Appendix D.

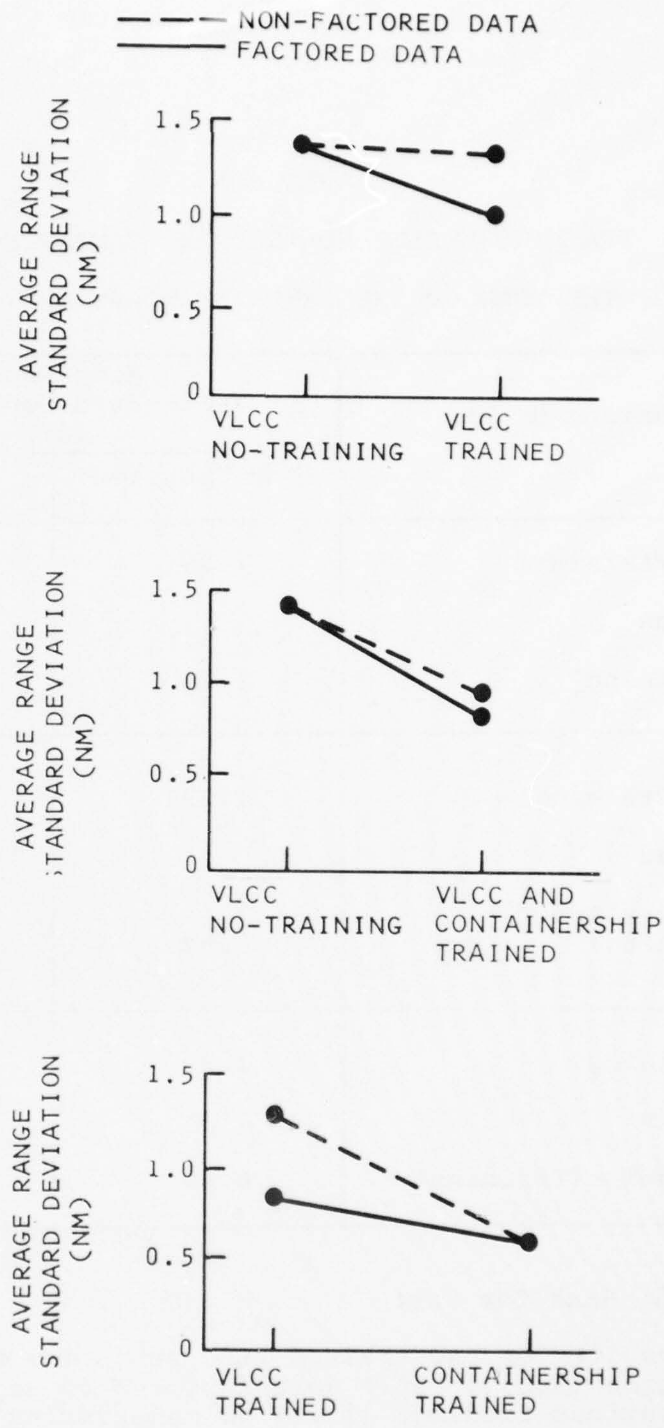


Figure 3-13. Average Range Standard Deviation and Training Relationships

TABLE 3-5

TRAINING VERSUS NO-TRAINING COMPARISONS

OF THE MEAN OF THE RANGE STANDARD DEVIATION

Comparison Groups	Mean Range Standard Deviation (nm)	
	Non-Factored	Factored**
VLCC (No-Training)	1.39	1.39
versus		*
VLCC (Training)	1.29	1.0
VLCC (No-Training)	1.39	1.39
versus		*
VLCC & Containership (Training)	0.99	0.85
VLCC (Training)	1.29	1.0
versus		*
Containership (Training)	0.69	0.69

*$p < 0.05$; Rank Sum Test

** The results for one trained VLCC subject's standard deviation (Subject #67) were factored to adjust for the spurious findings (12.19 nm maneuvering range) for the B4 run; see Table D-1 in Appendix D.

developed as a measure of the master's knowledge and understanding of the new rules, provides an estimate for each master that is independent of their grouping (it should be noted that although the post-test is independent of the groupings, the previous analyses have shown significant differences between the training and no-training groups regarding post-test scores). The post-test score was, therefore, used as a basis for comparison with behavior on the CAORF bridge.

Correlation coefficients, between the post-test scores and several behavioral measures are summarized in Table 3-6. All the masters, training and no-training groups, have been included in these analyses. These correlations are discussed in the following paragraphs.

Correlation coefficients between psychological tests and criteria are considered "good" when their absolute magnitude is above ± 0.4. They are considered "strong" with an absolute magnitude above ± 0.6. A level of significance may be associated with any correlation coefficient, similar to that for other statistical tests, to indicate the probability of obtaining the particular level of correlation by chance; in essence, it represents the confidence placed in the level of correlation obtained. A z score was calculated for each correlation coefficient to estimate the level from the normal distribution.

A significant correlation of -0.63 ($p < 0.05$) was obtained between the post-test score and the mean of range standard deviation for each master. The magnitude of the correlation is high, denoting a strong correspondence between the post-test score and the consistency of maneuver range. The negative sign denotes that the standard deviation decreased (the consistency of maneuver range increased) with the post-test score. Although the correlation does not explain a cause and effect relationship, it does demonstrate that the subjects' consistency of maneuver range behavior on the bridge was strongly related to their knowledge and understanding of the new rules. Figure 3-14 is a comparison of individual subject's standard deviation of range vs post-test scores as a function of grouping. A linear regression curve and the standard deviation of all range standard deviation values is also shown.

A second parameter relating to the consistency of performance is the mean CPA standard deviation. Whereas the range of maneuver initiation is directly and easily controlled by the master, the resultant CPA is a summary measure of the master's behavior. The resultant CPA in an encounter

situation is a function of a variety of factors, including the range of maneuver, maneuver magnitude, rate of maneuver, closing rate, crossing angle, and ship type. Nevertheless, it is controlled by the actions of the watch stander. The training program addressed the necessity for a safe CPA, and addressed several of the relevant factors in obtaining it.

TABLE 3-6

POST-TEST CORRELATION COEFFICIENTS

WITH BEHAVIORAL MEASURES

Behavioral Measures per Individual Master	Post-Test Correlation Coefficient#
Mean Range Standard Deviation	-0.63*
Mean CPA Standard Deviation	0.02
Mean Range	-0.42*
Mean Number of Course Changes	-0.50**
Mean Maneuver Magnitude	0.11
Mean CPA	0.32***

Pearson Product Moment Correlation Coefficient

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

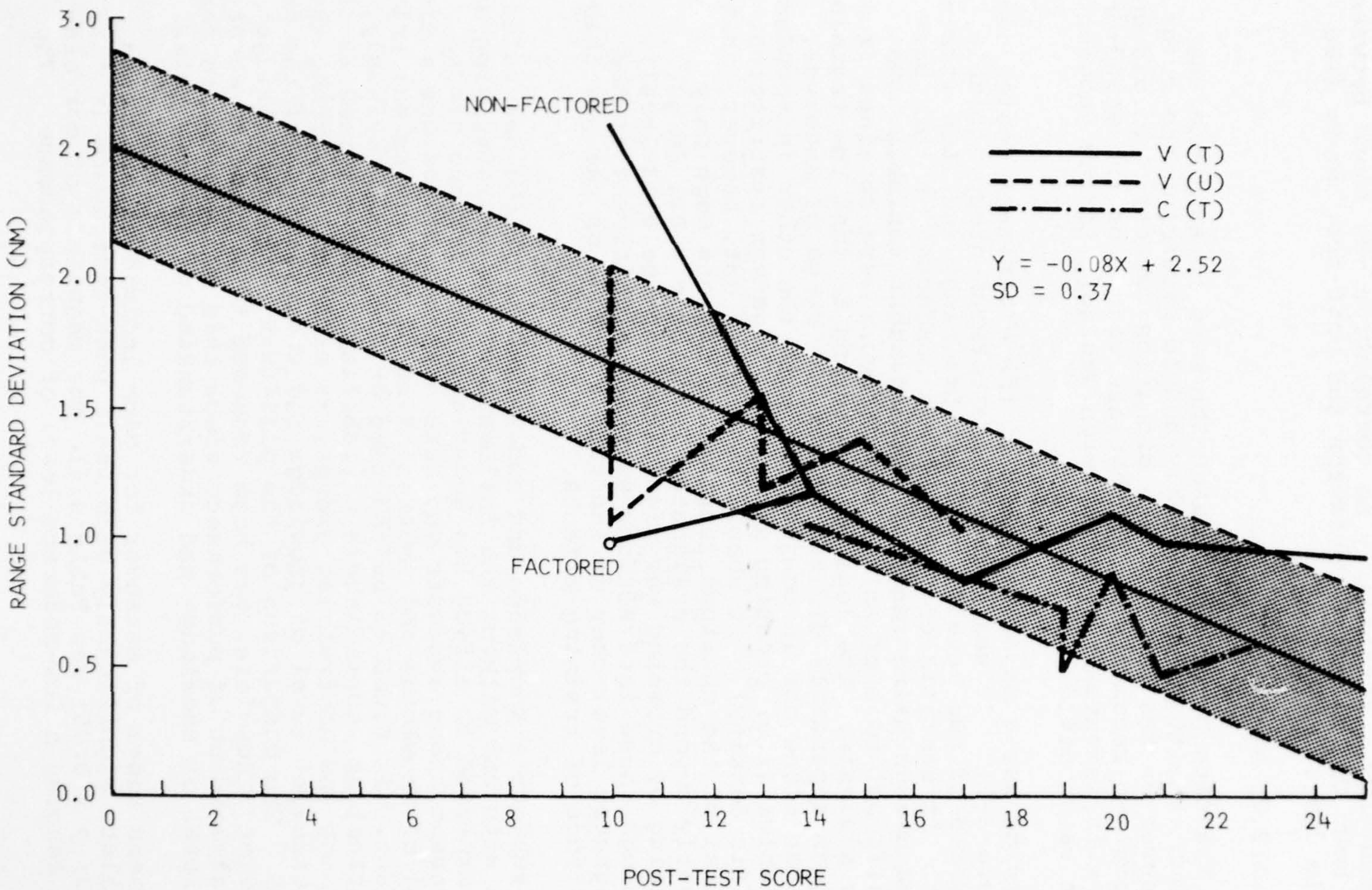


Figure 3-14. Post-Test Score vs Range Standard Deviation

The program did not, however, address the CPA size or consistency. Essentially no correlation was found between the mean CPA standard deviation and post-test score (see Table 3-6).

3.2.1.2.2 Range

The training program addressed the need to evaluate the encounter situation thoroughly and to determine the range of maneuver on the basis of the situation factors. It did not attempt to recommend an appropriate range for the stand-on vessel's maneuver. That decision was left to the judgment of each watch officer.

Training was a major variable of the experiment design (see Figure 2-1). It was treated as a between-group variable composed of two levels, VLCC (no-training) and VLCC (training). An analysis of variance was conducted on this balanced design using range as the dependent variable. No significant main or interaction effects were obtained from this analysis. The logical conclusion is that the training program apparently did not affect the range of maneuver, neither alone nor in conjunction with the other independent variables (i.e. crossing situation, maneuver restriction, traffic density). It should be pointed out, however, that several of the obtained interaction effects were only slightly beyond the designated level of $p < 0.1$ (e.g., training by crossing was significant at the 0.13 level). Although these interactions were not significant at the designated level they do indicate a trend, or the possible existence of training effects.

The subject's knowledge and understanding of the new rules, both with and without the influence of the training program was expected to affect his behavior. The trained groups represent those subjects who were expected to possess a high level of knowledge and understanding of the new rules; this, in fact, was found to be the case as discussed previously. Nevertheless, considerable variability still remained in the training and no-training groups, as expected, regarding the individuals' level of knowledge and understanding of the new rules. The comparison of the post-test score with bridge behavior, therefore, has been reasoned to provide an accurate assessment of performance since this score accounts for the level of knowledge and understanding of the new rules.

The mean range of maneuver for each individual was found to correlate significantly with their post-test score ($r = -0.42$; $p < 0.05$; see Table 3-6). The magnitude of correlation denotes a low-moderate level of correspondence. The

negative sign indicates that the masters with higher post-test scores tended to initiate their maneuver at a closer range than those with lower scores. This finding indicates the anticipated relationship between the masters' level of knowledge and understanding of the new rules, and the mean range of their maneuvers.

3.2.1.2.3 Maneuver Behavior

The ownship maneuver, like the range at which the maneuver is initiated, is under the direct control of the master. The training program addressed various aspects of the maneuver including the necessity for a large maneuver (e.g., Rule 8b), the effectiveness of a course change alone (e.g., Rule 8c), and the recommendation that the stand-on vessel not change course to port (Rule 17c). Several aspects of the maneuver were investigated in relation to the effects of the training program; these were 1) the type of maneuver, 2) the number of course changes comprising the maneuver, and 3) the overall magnitude of the maneuver. The stand-on vessel's initial maneuver for the primary target, a give-way vessel, was investigated in this regard. The initial maneuver consisted of the speed and/or course changes taken to avoid the collision. Start of the maneuver was readily identified as the time when the stand-on vessel altered course and/or speed. The maneuver was concluded when ownship's actions stabilized or reversed (e.g., if the maneuver was to the right, the maneuver ended when ownship ceased turning to the right). Under this approach, the maneuver often consisted of a series of course and/or speed changes. The raw maneuver data for all subjects are tabulated in Appendix D, Tables D6 through D8.

The type of maneuver was investigated by grouping all maneuvers into two categories: 1) right course change, and 2) non-right maneuvers (i.e., speed changes and left course changes). A further breakdown was not used because of the small number of non-right maneuvers that occurred (i.e., 19 non-right maneuvers out of a total of 144 maneuvers). The proportion of non-right maneuvers was investigated to determine if it was related to the training variable. The no-training group was found to have made significantly more non-right maneuvers than the training group (VLCC and containership), as measured by the Fisher test (see Table 3-7). The proportions of non-right maneuvers for the untrained and trained groups were 10/48 and 9/96, respectively. The proportions of non-right maneuvers of the VLCC no-training and training groups, however, were not significantly different. This finding appears to indicate that the above significant non-right maneuver difference is actually between the VLCC and containership, and is thus not an

TABLE 3-7

SUMMARY OF NON-RIGHT MANEUVERS ANALYSIS -

TRAINING VARIABLE

Group	Proportion Of Non-Right Maneuvers	Level Of Significance
No-Training	10/48	p =0.05*
Training	9/96	
VLCC (No-Training)	10/48	p =0.33
VLCC (Training)	7/48	
VLCC (No-Training)	10/48	p =0.02*
Containership (Training)	2/48	
VLCC (All)	17/96	p =0.03*
Containership (Training)	2/48	
VLCC (Training)	7/48	p =0.06*
Containership (Training)	2/48	

(Note that the test used was the Fisher Test)

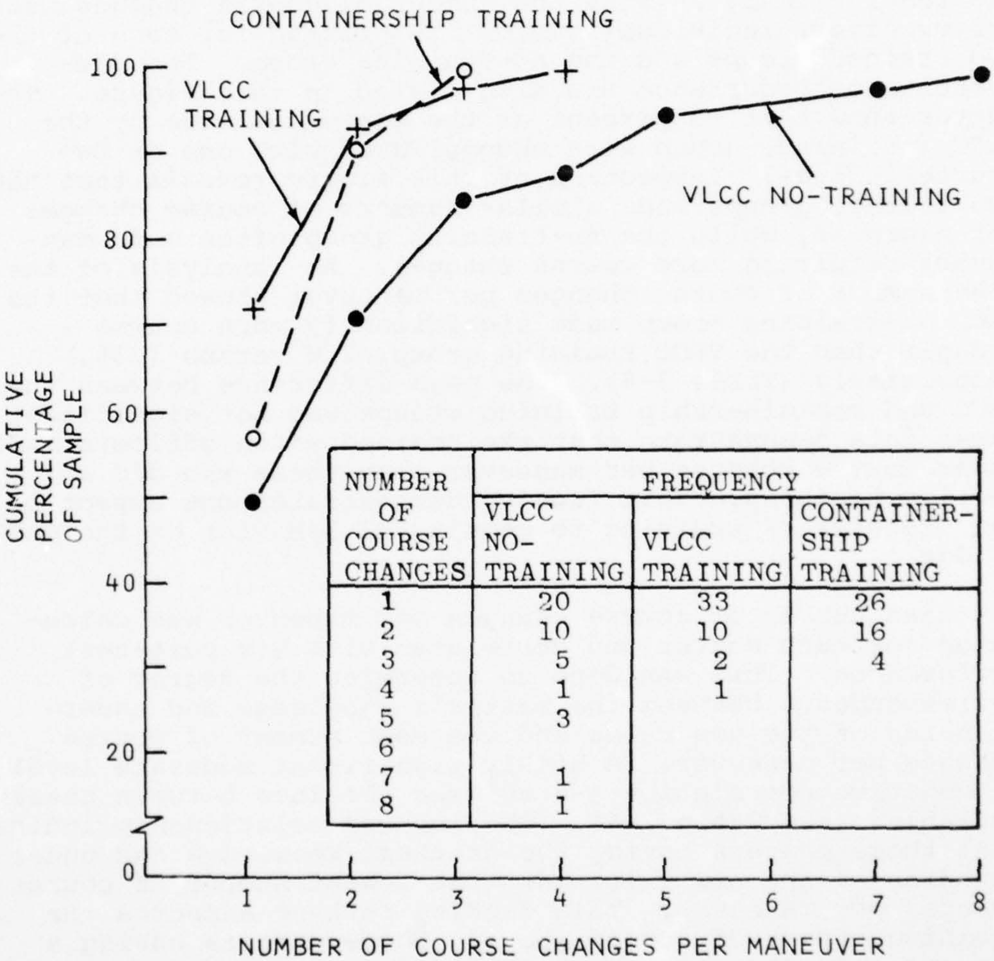
* Indicates that results are significant

effect of training. This contention is supported by three additional findings (refer to Table 3-7); the non-right maneuver proportions were significantly different between 1) the VLCC (no-training) and containership (training) groups, 2) the VLCC (no-training and training) and containership (training) groups, and, 3) the VLCC and containership training groups (see Table 3-7).

The practice of making a series of small course changes to accomplish a maneuver was discouraged by the training program. Hence, the number of course changes per completed maneuver was investigated to evaluate the effect of training. All right and left maneuvers were considered in this investigation. The cumulative percentage of maneuvers is plotted in Figure 3-15 by the number of course changes made per maneuver. Individual curves are plotted for each of the two trained groups and the no-training group. The frequencies of occurrence are also listed in this figure. The curves show that 93 percent of the maneuvers made by the VLCC (training) group were accomplished with one or two course changes. Inspection of this figure reveals that the two trained groups made similar numbers of course changes per maneuver, while the no-training group often made maneuvers requiring more course changes. An analysis of the mean number of course changes per maneuver showed that the VLCC no-training group made significantly more course changes than the VLCC training group, 2.2 versus 1.36, respectively (Table 3-8). The mean difference between the VLCC and containership training groups was not significant. These data demonstrate that the trained watch officers made fewer course changes per maneuver than those who did not receive training. This finding demonstrates one aspect of the transfer of training to meaningful behavior on the CAORF bridge.

The mean number of course changes per maneuver was calculated for each master and correlated with his post-test performance. This was done to determine the degree of correspondence between the master's knowledge and understanding of the new rules and the mean number of course changes per maneuver. A highly significant moderate level of negative correlation (-0.50) was obtained between these variables (see Table 3-6). The inverse relationship indicates that those masters having the greatest knowledge and understanding of the new rules make the fewest number of course changes per maneuver. This finding further supports the training effect discussed above. Those masters having a greater understanding of the new rules, as provided by the training program and measured by the post-test, are likely to be more aware of the importance of making readily observable large maneuvers.

The number of course changes per maneuver was also correlated with measures of range and CPA. The results of these analyses are summarized in Table 3-9. The correlations with range and CPA were all of a low level, four of which were significant. These results show that the behavioral measures of range and CPA are largely independent of the number of course changes per maneuver. This appears to be so for the VLCC no-training group as well as the VLCC and containership training groups. The training program, although it addressed each of these three variables, did not emphasize a relationship between them. Perhaps of greater importance, the significantly low correlations demonstrated a degree of independence of range and CPA from the number of course changes per maneuver.



NUMBER OF COURSE CHANGES	FREQUENCY		
	VLCC NO-TRAINING	VLCC TRAINING	CONTAINER-SHIP TRAINING
1	20	33	26
2	10	10	16
3	5	2	4
4	1	1	
5	3		
6			
7	1		
8	1		

Figure 3-15. Number of Course Changes Per Maneuver By Training and Ship Type Variables

The magnitude of maneuver was addressed by the training program to the extent that a large maneuver, one that may be readily recognized by the other vessel, was recommended. Another important consideration affecting the maneuver magnitude is that it be large enough to achieve an acceptable CPA. This consideration was not emphasized during the training program. Other factors, such as the ship type, range at maneuver, and encounter geometry, may affect the master's decision in selecting a maneuver. The contributing factors in the selection of a maneuver magnitude, therefore,

TABLE 3-8

SUMMARY - MEAN NUMBER OF COURSE CHANGES PER MANEUVER, TRAINING VARIABLE

Analysis	Mean Number of Course Changes	t Score+	Degrees of Freedom
VLCC (No-Training)	2.20		
vs		1.54*	10
VLCC (Training)	1.36		
VLCC (Training)	1.36		
vs		0.78	10
Containership (Training)	1.53		

+Students "t" Test

*$p < 0.01$

are somewhat complex, reflecting other than the training variable. Nevertheless, it is a direct manifestation of the master's behavior as he initiates his maneuver, monitors the interacting effect of his actions, and either continues or terminates his swing based on his assessment of the situation. The bar graph of Figure 3-16 shows the mean maneuver magnitude made by each of the three groups. The trained groups made the largest (VLCC - 55°) and smallest (containership - 25°) average maneuvers. The no-training group's average maneuver fell in between these two extremes (VLCC - 40°). The relative size of the maneuver magnitudes (average VLCC vs containership) reflects the potential CPAs available to each ship type.

TABLE 3-9

CORRELATIONS BETWEEN THE NUMBER OF COURSE CHANGES PER MANEUVER AND CPA, AND RANGE, AS A FUNCTION OF THE TRAINING GROUP

Variable	Subject Groupings+		
	VLCC No-Training	VLCC Training	Containership Training
CPA and Number of Course Changes per Maneuver	-0.08	0.24**	0.30**
Range and Number of Course Changes per Maneuver	0.28*	0.22**	0.14

+Pearson Product Moment Correlation Coefficient

* $p < 0.05$

** $p < 0.07$

The mean maneuver magnitude for each master was correlated with his post test performance. Essentially, no correlation was found between the mean maneuver magnitude and post-test performance (see Table 3-7). This finding, together with other findings, indicates the training program had little or no effect on the watch officer's maneuver magnitude.

3.2.1.2.4 Closest Point of Approach (CPA)

The CPA is an important variable relating to the safety of a multi-ship encounter. It represents a summary behavioral measure, the goal of the stand-on vessel's maneuvers. The resultant CPA, as noted earlier, is based on a variety of factors. It is, however, generally under the control of the watch officer and the CPA represents the product of, among other factors, the range and magnitude of maneuver.

The training program stressed that a safe CPA should be attained, and explored the various factors that affect its attainment. Furthermore, the training program stressed that the desired CPA may depend on the particular situation, although particular values of CPA were <u>not</u> recommended. Earlier findings of this study showed that the consistency of attained CPAs, which was not addressed by the training program, was not related to the subject's level of knowledge

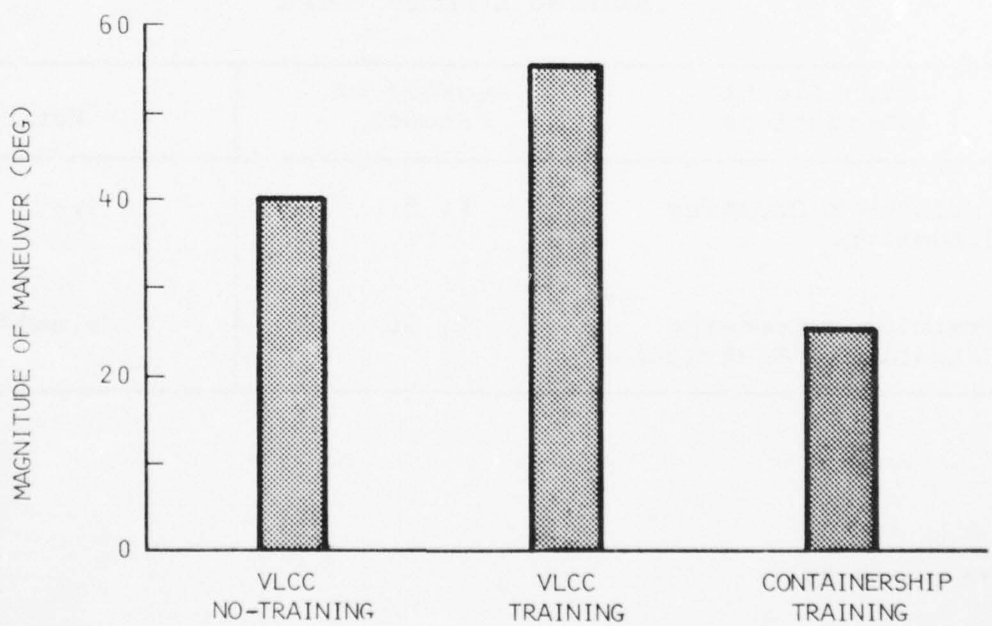


Figure 3-16. Magnitude of Maneuver - Training and No-Training Groups

and understanding of the new rules (see Table 3-6). These findings did not address the relationship between the CPA magnitude and training. Several analyses, below, address this variable.

An analysis of variance was conducted on the balanced training design, treating CPA as the dependent variable (see Figure 2-1). Training, with two levels (VLCC no-training; VLCC training), was treated as the between-subject variable. There was no first order (main) training effect. The training effect was significant in two interaction effects, one with crossing situation and one with crossing situation by restriction (see Table 3-10).

The two-factor interaction ($p < 0.09$, see Figure 3-17) shows that the training and no-training groups achieved similar CPAs of about 0.5 nm in the clear-cut crossing situation. In the ambiguous crossing situation, however, the trained group attained a larger CPA of about 0.56 nm, while the untrained group attained a smaller CPA of about 0.37 nm.

TABLE 3-10

SUMMARY OF ANALYSIS OF VARIANCE

TRAINING EFFECTS - CPA

Significant Interactions	Degrees of Freedom	F Ratio
Training X Crossing Situation	1, 5	4.49*
Training X Crossing Situation X Restriction	1, 10	5.86**

* $p < 0.09$

** $p < 0.07$

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RULES OF THE ROAD TRAINING INVESTIGATION. (U)
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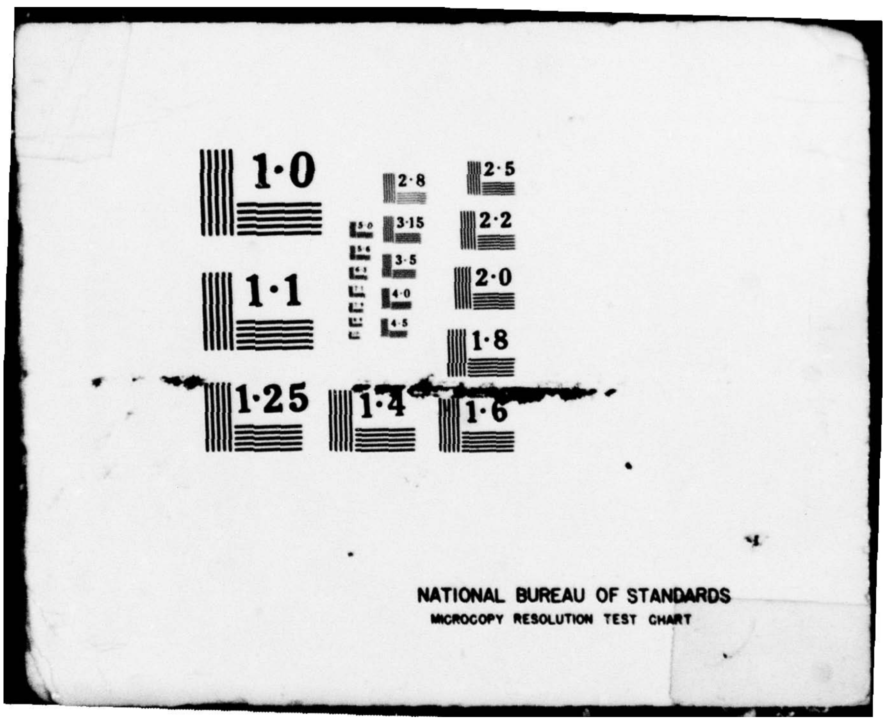
1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
1·1
1·8
1·25
1·4
1·6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

The relevant maneuver factors contributing to this interaction are summarized in Table 3-11. The mean range at which both groups maneuvered under clear-cut conditions was 3.86 nm. The no-training group maneuvered at the same range under the ambiguous conditions as well. The training group, however, maneuvered at a much greater range (4.66 nm), under the ambiguous conditions. The training group, which has been shown to have significantly greater knowledge and understanding of the new rules, appears to have taken advantage of Rule 14c and assumed the situation was head-on. (Note: Rule 14c - When a vessel is in doubt as to whether a head-on situation exists, she shall assume that it does exist and act accordingly.) By so doing, they did not have to stand-on, and were free to take earlier action.

The maneuver magnitudes of both the trained and no-training groups were proportionately less in the ambiguous situation, as compared with the crossing situation (see Table 3.11). Hence, since the no-training group maneuvered at the same range regardless of the situation, the CPA they attained in the ambiguous situation was less because their maneuver magnitudes were smaller in this situation. The increased

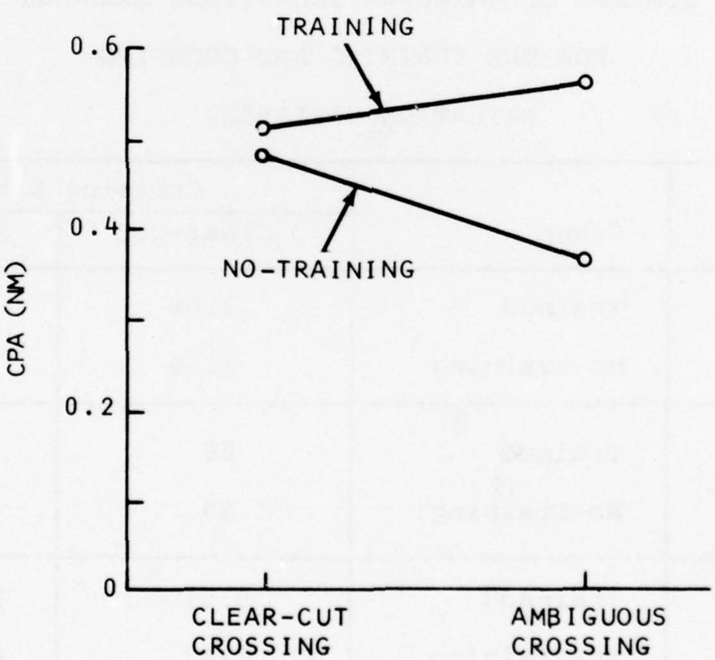

Figure 3-17. Interaction of Training and Crossing Situation

range at which the training group maneuvered in the ambiguous situation, however, more than offset their smaller maneuver magnitude in this situation. This offsetting behavior resulted in a slightly larger CPA. These findings demonstrate effects of the training program on the master's interpretation of the rules and situations while in an operational context on the bridge, as well as measured behavioral differences. The training program appears to have affected the subject's interpretation of the crossing/head-on situation; the trained watch officers apparently interpreted the ambiguous situations as ambiguous or head-on, and followed the rules in taking early action in that situation.

The significant ($p < 0.07$, Table 3-10) three-factor interaction for CPA was between training, crossing situation and restriction variables (see Figure 3-18). Inspection of Figure 3-18 shows that the two-factor interaction discussed above (see Figure 3-17) appears to have been a function of

TABLE 3-11

SUMMARY OF MANEUVER BEHAVIORAL MEASURES

FOR THE TRAINING AND CROSSING

SITUATION VARIABLES

Measure	Group	Crossing Situation	
		Clear-Cut	Ambiguous
Range (nm)	Trained	3.68	4.66
	No-training	3.86	3.86
Maneuver Magnitude (degrees)	Trained	66	35
	No-Training	50	29
CPA (nm)	Trained	0.51	0.56
	No-Training	0.47	0.37

restriction; the two-factor interaction was present with the right restriction and absent when no restriction existed. The maneuver data (i.e., range and maneuver magnitude) reveal that the same type of rationale put forth to explain the two-factor interaction also applies to this three-factor interaction. Table 3-12 lists the mean values for range, maneuver magnitude, and CPA for the three relevant variables. Inspection of these data show that the trained group consistently maneuvered at a greater range in the ambiguous situation, regardless of the presence or absence of a restriction. The range of maneuver for this group was also consistently greater when the right restriction was present compared to when it was absent. In a manner similar to that noted above, the trained group made smaller maneuvers in the ambiguous situations than in clear-cut ones. The increase in range of maneuver from clear-cut to ambiguous was offset by the large reduction in maneuver magnitude for the training group with no-restriction as indicated by the same attained CPA in both cases (0.55 nm). Another way of looking at this is that the larger maneuver under clear-cut conditions (76°) was necessary to compensate for the smaller range (3.27 nm) to get the same CPA.

When the right restriction was present, the training group maneuvered at a greater range for the ambiguous situation, with somewhat smaller maneuver magnitude (compared to the

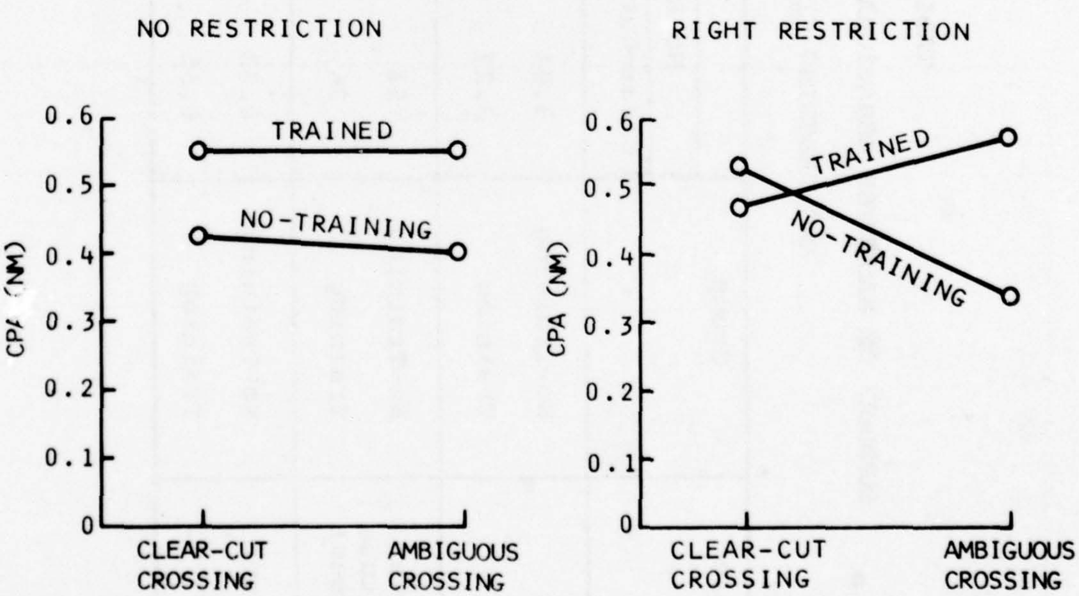

Figure 3-18. Interaction Between Training, Crossing Situation, and Maneuver Restriction

TABLE 3-12

SUMMARY OF MANEUVER BEHAVIORAL MEASURES-TRAINING, RESTRICTION AND CROSSING SITUATION VARIABLES

Measure	Group	Condition			
		No Restrictions		Right Restrictions	
		Clear-Cut	Ambiguous	Clear-Cut	Ambiguous
Range (nm)	No-Training	3.01	3.93	4.72	3.80
	Training	3.27	4.37	4.10	4.92
Maneuver Magnitude (Degrees)	No-Training	54	36	44	23
	Training	76	31	55	38
CPA (nm)	No-Training	0.42	0.40	0.51	0.33
	Training	0.55	0.55	0.47	0.57

clear-cut situation) and attained a somewhat larger CPA; that is, the larger range (4.92 nm) compensated for the smaller maneuver (38°).

For encounters without restrictions, the untrained group's performance was similar to the performance of the trained group. They increased the range of maneuver from clear-cut to ambiguous crossing, decreased their average maneuver magnitude, and attained approximately the same CPA. With restrictions present though, their actions differed. They maneuvered at a smaller range for ambiguous encounters and decreased their average maneuver magnitude (to a small value, 23°) and, therefore, attained a closer CPA (0.33 nm). This behavior most probably occurred with the no-training group since they were preoccupied with restrictions, and failed to take advantage of Rule 14c. The training group did take advantage of Rule 14c, which allows an ambiguous situation to be defined as head-on, thereby, relieving themselves of stand-on obligations and allowing an earlier maneuver. The results are also a reflection of the maneuvering capability of the VLCC. An average course change of 23°, at approximately 4 miles will result in a very small potential CPA.

3.2.1.2.5 Pooled Effects

Statistically significant effects were also derived from the training effect analyses of variance for the three variables of crossing situation, maneuver restriction and traffic density when the comparisons were made within the subject variables using all of the VLCC findings (both trained and untrained) as the basis of the analyses. The significant results of the analyses for range and CPA are indicated in Table 3-13.

It can be seen that in the training effect design, the range at maneuver was greater for maneuver restriction conditions (4.4 nm) than for conditions with no maneuver restrictions (3.6 nm, Figure 3-19). This difference in the range at which VLCC officers took evasive action as a function of maneuvering restrictions was significant ($p \approx 0.06$, Table 3-13). It appears that this finding is due to the VLCC watch officers' (both trained and untrained) concern for the maneuvering restrictions on their starboard side (oil rigs in the Gulf of Mexico watch and the Matanilla Shoals in the Florida Straits watch). The interpretation of this finding is further substantiated by the fact that for those cases in which non-standard maneuvers (speed changes and/or altering of course to port) were executed, an overwhelming majority (17 of 19) occurred under conditions of right maneuver

restrictions. Furthermore, in the 24 runs that included maneuver restrictions for each treatment group, trained VLCC watch officers executed non-standard maneuvers in 29.9 percent of these cases (7 of 24); untrained VLCC watch officers executed non-standard maneuvers in 37.5 percent of the cases (9 of 24); and trained containership officers in only 4.2 percent of the cases (1 of 24 runs). Thus, maneuvering restrictions also had a differential effect on the type of evasive maneuver as a function of ship type, i.e., VLCC officers executed substantially more non-standard maneuvers than did containership watch officers and the restrictions caused by oil rigs caused more concern that those imposed by shallow water.

Table 3-13 shows a significant two-way interaction ($p \approx 0.08$) between crossing situation and maneuver restrictions in the training effect design (VLCC trained and untrained) for range at maneuver. It can be seen from Figure 3-20 that with the right side maneuver restrictions, all VLCC officers maneuvered at the same average range (4.40 nm) regardless of the type of crossing situation (because the concern for

TABLE 3-13

SUMMARY OF SIGNIFICANT EFFECTS FROM

ANALYSIS OF VARIANCE - TRAINING DESIGN

Effects	Parameter	F Ratio	Degrees of Freedom
Restriction	Range	6.12 ($p \approx 0.06$)	1, 5
Restriction X Crossing	Range	4.93 ($p \approx 0.08$)	1, 5
Crossing X Traffic Density	CPA	6.45 ($p \approx 0.05$)	1, 5

maneuver restrictions appears to cancel out the effect of type of crossing situation) and that this range was larger for restrictions than no restrictions. With no restrictions, however, it can be seen (Figure 3-20) that VLCC officers maneuvered at a substantially larger range (4.16 nm) for ambiguous crossings than for clear-cut crossings (3.13 nm). As indicated previously with regard to ambiguous crossings, it appears that the mariner interprets these situations as head-on and, therefore, is relieved of stand-on vessel obligations.

A significant interaction effect ($p \approx 0.05$) was also found between crossing situation and traffic density in the training effect design for CPA attained, and the nature of the interaction is shown in Figure 3-21. Comparing ambiguous to clear-cut crossings, it can be seen (Table 3-14) that VLCC officers maneuvered at a greater range under ambiguous crossing situations (4.27 nm) as compared with clear-cut crossing situations (3.78 nm), but the magnitude of the maneuver was much less (32° vs 58°). Therefore, range at maneuver and the magnitude of the maneuver compensated for each other, resulting in approximately the same CPA (0.50 nm vs 0.47 nm) for the two types of crossing situations. Further inspection of the results for crossing by traffic combinations (Table 3-14) reveals that although VLCC officers executed similar maneuvers for low traffic conditions, and

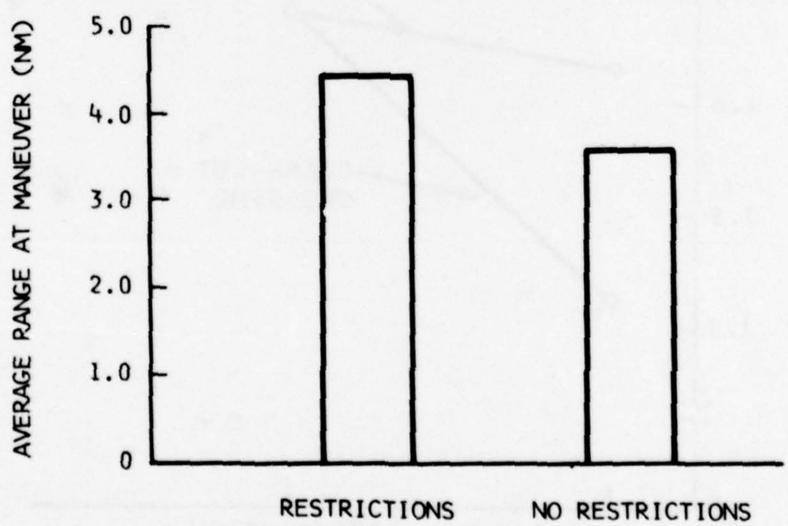

Figure 3-19. Average Range at Maneuver as a Function of Maneuver Restriction

obtained comparable results, this was not the case with high traffic situations. There was an increase in range between clear-cut and ambiguous crossings (3.58 nm vs 3.97 nm) and a decrease in maneuver magnitude (53^{o} vs 30^{o}) but the attained CPA did not increase with range as before, but decreased from 0.56 nm to 0.43 nm. This anomaly was caused by the size of the maneuvering range for ambiguous crossing situations. Even though the range increased for the ambiguous crossing case, it did not fully compensate for the decrease in maneuvering magnitude since only a small potential CPA can result from a 30^{o} course change with a VLCC vessel.

3.2.1.3 Summary Discussion

The training program was designed to instruct the subjects in the changes to the International Rules of the Road regarding potential collision situations. The training program attempted to provide them with increased knowledge and understanding of the new rules. It was developed so that the effect of training would transfer into more consistent stand-on vessel maneuvering range, as inconsistent

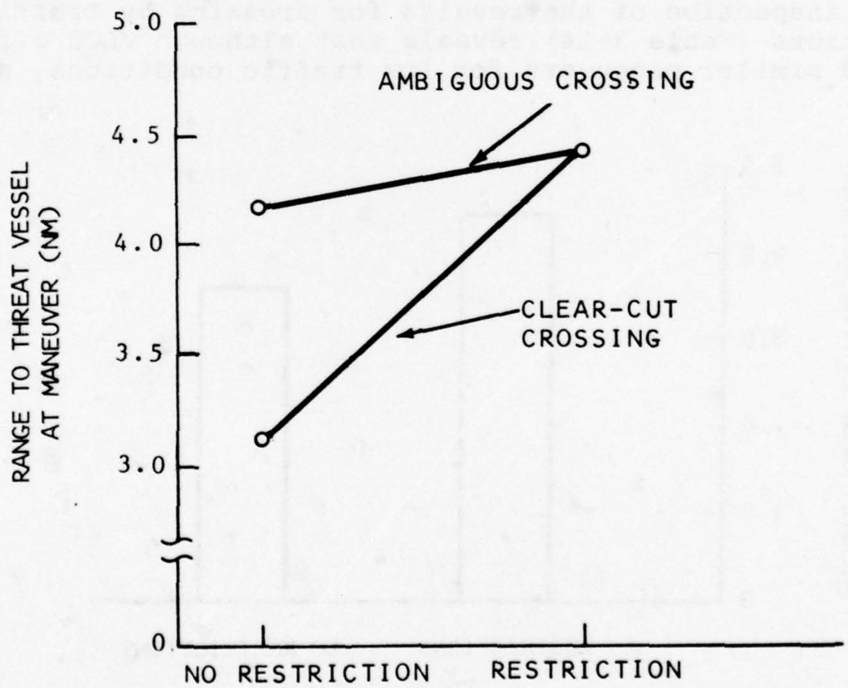

Figure 3-20. Interaction of Crossing Situation and Maneuver Restriction - Range

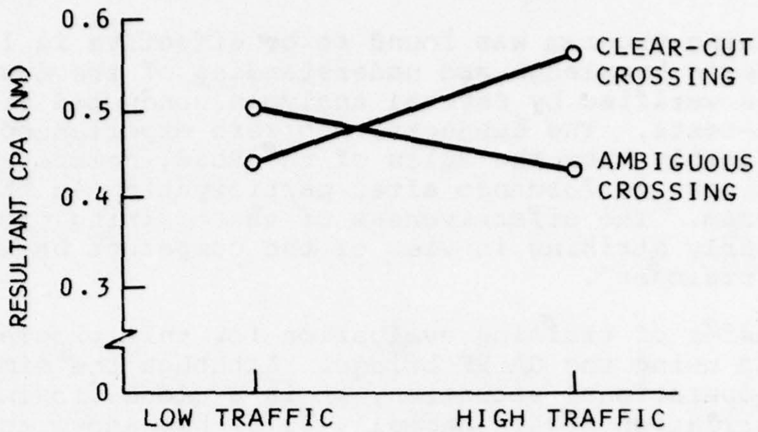

Figure 3-21 *Interaction of Crossing Situation and Traffic Density - CPA*

TABLE 3-14

PERFORMANCE AS A FUNCTION OF SCENARIO CONDITION

-TRAINED DESIGN-ALL VLCC

Measure	Crossing	Traffic		
		Low	High	All
Range at Maneuver(nm)	Clear-cut	3.97	3.58	3.78
	Ambiguous	4.59	3.97	4.27
Maneuver *Magnitude* (degrees)	Clear-cut	64	53	58
	Ambiguous	34	30	32
Resultant CPA (nm)	Clear-cut	0.43	0.56	0.50
	Ambiguous	0.51	0.43	0.47

maneuvering was believed to be a possible disadvantage of the new rules.

The training program was found to be effective in increasing the master's knowledge and understanding of the new rules which was verified by several analyses conducted via pre- and post-tests. The subjects, who were experienced mariners and presumably knew the Rules of the Road, demonstrated improved test performance after participating in the training program. The effectiveness of the training program is particularly striking in view of the competent backgrounds of the "trainees".

The transfer of training evaluation for this program was conducted using the CAORF bridge. Although the simulator is not the operational situation, it is a close facsimile. A CAORF validation study (Hammell, 1976) has shown that mate behavior on CAORF is similar to their behavior at sea. Furthermore, Hammell showed similarities in ship performance measures (e.g., CPA) on CAORF and at sea. Hence, CAORF represents a reasonable vehicle for an initial evaluation of the transfer of training. Later investigations should complete this process by evaluating the transfer of training between the simulator and the at-sea situation, or, alternatively, evaluating the effectiveness of the training program in the operational situation.

The investigation into the transfer of training was designed to establish if the training program had an effect on the masters' behavior on the COARF bridge. A variety of behavioral variables were used to investigate this training effect: standard deviation of the initial range at maneuver (i.e., range consistency), maneuver range, maneuver type, number of course changes per maneuver, maneuver magnitude, CPA, and standard deviation of CPA (i.e., CPA consistency). The analyses demonstrated that the effects of the training program did transfer into modified behavior on the bridge. Perhaps the most important finding was the strong relationship established between training and the consistency of the maneuver range. The trained masters, and those scoring highest on the post-test, were generally found to have the greatest consistency in selecting the range for the maneuver. This was a primary objective of the training program. It demonstrated that training can increase the consistency or predictability of maneuver range.

Several other aspects of behavior were likewise shown to be significantly affected by the training program. The training program resulted in masters' making significantly fewer course changes per maneuver and by maneuvering at larger

ranges in the ambiguous situations. These desirable behavioral differences can be traced to implications in the international rules, and demonstrate the transfer of training.

The post-test scores were found to be significantly higher for the trained groups than the no-training group, showing their dependence on classroom training. Several behavioral variables were found to be related to the post-test performance. The consistency of maneuver range was highly related to post-test performance. The mean maneuver range was found to decrease as the post-test score increased. The number of course changes per maneuver also was less for the higher test scores. Several other measures (e.g., maneuver magnitude) did not show a relationship with the post-test performance. These findings complement those pertaining to the specific training and no-training groups. They also support the contention that considerable variance existed in the groups because of the masters' level of knowledge and understanding of the new rules. Finally, they demonstrate transfer of training to behavior on the simulator.

The variety of findings resulting from these training analyses begins to paint a picture of the effects of the training program, and knowledge and understanding of the rule changes. Watch officers who participated in the training program demonstrated a greater knowledge and understanding of the new rules. They have been shown to use this increased capability to interpret situations better and use the rules more effectively. For example, they maneuver at a greater range in the ambiguous situation, as suggested by Rule 14c. The range at which the trained masters maneuver appears to differ from that of the untrained masters in certain situations, although the nature of this difference is unclear. The consistency in the range at which they maneuver is, however, much greater than the untrained master. The trained masters' combination of larger range, fewer course changes, and larger maneuver magnitude yield a higher CPA than the untrained masters in some situations. It should be noted that the investigation showed these variables to be independent of each other in the situations used. The fact that the untrained masters made more course changes per maneuver suggests that they may have been less decisive with regard to the appropriate actions to take. The findings of this investigation, when significant and even when trends that were not significant were detected, demonstrate that the training program has resulted in improved performance by the masters on the bridge.

3.2.2 Ship Type Effect

One of the two experiment designs of the Rules of the Road Training Investigation was used to determine if differences in behavior exist between watch officers of two different classes of ships operating under the new International Rules of the Road. The experiment design shown in Figure 2-2, allowing a comparison of trained VLCC and trained containership groups, was applied to satisfy this objective. As was the case with the training design, the performance measurement parameters for these stand-on encounters were range to target ship at time of maneuver, attained CPA to the primary target ship, and maneuver qualities (such as maneuver magnitude, number of course changes, and non-standard maneuvers).

3.2.2.1 Range at Maneuver and CPA Attained

Based on the data collected in this experiment, Figure 3-3 depicts the cumulative probability of a stand-on vessel maneuver by containership and VLCC watch officers as a function of range to the give-way threat vessel. It can be seen that the two plots are essentially the same, with the exception that slight variations are noted between ship type as range decreases below 3 nm. This slight variation was in large part attributable to one VLCC watch officer in 75 percent (six out of eight) of his test runs.

The cumulative probability, by ship type, of a stand-on vessel achieving a resultant CPA to the give-way threat vessel is presented in Figure 3-6. Marked differences between ship types can be observed. Realizing that larger CPAs are indicative of larger safety margins, it can be seen from Figure 3-6 that VLCC watch officers attained a resultant CPA of 3/4 of a mile or less in 80 percent of the cases, whereas containership officers achieved a CPA of 3/4 of a mile or less in 40 percent of the cases.

Since the ogives of Figure 3-6 are actually the averaging of the different variables, the cumulative probability of attained CPA by ship type and one of the more ship-type sensitive variables (i.e., crossing situation) is depicted in Figure 3-22. It can be seen that differences still exist between attained CPAs for the different vessels/mariners when subjected to this further analysis. The trained VLCC mariners attained comparable CPAs for the clear-cut and ambiguous crossing encounters, while the trained containership watch officers showed a marked decrease in attained CPAs for the ambiguous crossing situations compared with their clear-cut crossing encounters. Yet, the containership

mariners in ambiguous crossing encounters still show a cumulative attained CPA which is larger than either of the groups of VLCC watch officers.

3.2.2.2 Analysis of Variance Significant Effects

3.2.2.2.1 Ship Type Effects

Statistically significant effects ($p < 0.10$) derived from the analysis of variance for range at maneuver and CPA attained are presented in Tables 3-15 and 3-16. These represent differences found when a comparison of the trained VLCC group was made with the trained containership group.

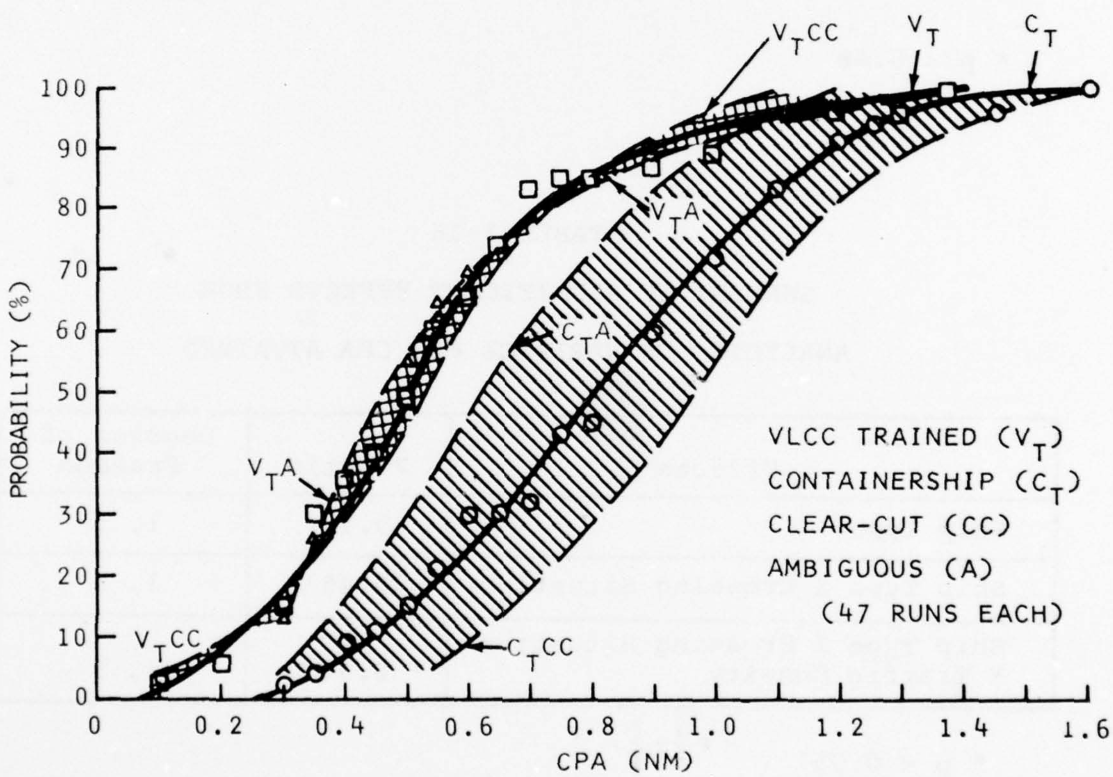

Figure 3-22. CPA Cumulative Probability - VLCC Trained and Containership Trained

TABLE 3-15

SIGNIFICANT EFFECTS FROM ANALYSIS

OF VARIANCE FOR RANGE AT MANEUVER

Effects	F Ratio	Degrees of Freedom
Ship Type X Crossing Situation X Traffic Density	4.98*	1, 5

* $p < 0.08$

TABLE 3-16

SUMMARY OF SIGNIFICANT EFFECTS FROM

ANALYSIS OF VARIANCE FOR CPA ATTAINED

Effects	F Ratio	Degrees of Freedom
Ship Type	9.13*	1, 5
Ship Type X Crossing Situation	30.45**	1, 5
Ship Type X Crossing Situation X Traffic Density	8.44*	1, 5

* $p < 0.05$
** $p < 0.005$

As can be seen in Figure 3-23 the average range at which an evasive maneuver was executed for containership watch officers (4.08 nm) was almost identical to that for VLCC watch officers (4.16 nm). This difference was not significant ($p < 0.25$). However, as seen in Figure 3-24, containership officers achieved a larger average resultant CPA (0.8 nm) to the threat vessel than did VLCC officers (0.5 nm). This difference was statistically significant ($p < 0.05$, Table 3-16, Ship Type). This significant main effect (ship type) which was found for resultant CPA cuts across all variables and therefore may be attributed to one or more of the following factors in considering differences between the two types of vessels: 1) the range at maneuver, 2) the magnitude of the maneuver, and 3) scenario considerations and/or vessel handling characteristics.

With regard to range at maneuver, there was no difference between VLCC and containership watch officers, as stated earlier. In comparing the two ship types with respect to the magnitude of maneuvers (i.e., the heading change commanded), a marked difference was found between the average heading change for VLCCs (55°) and containerships (25°). Thus, containership officers 1) executed much smaller maneuvers, 2) maneuvered at the same range as VLCC officers,

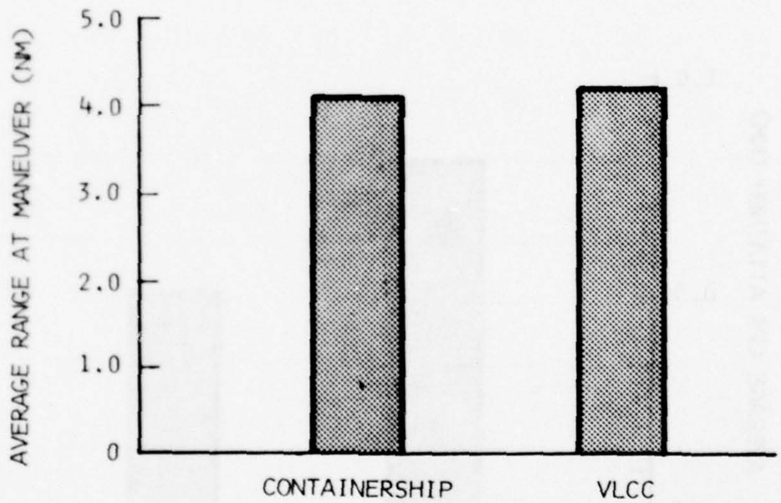

Figure 3-23. Average Range at Maneuver for Trained VLCC and Containership Groups

and still achieved larger CPAs. The post-experiment-run analyses that were discussed earlier in the "Resultant Attained CPA to Primary Threat Vessel" subsection, partially account for the differences in attained CPA by the different ship type watch officers. When efficient maneuvers were executed at approximately the same range to target vessel, the analyses showed that containership officers had a larger potential CPA available to them, with the use of much smaller maneuver magnitudes, compared with the VLCC officers. Therefore, vessel handling characteristics provide part of the explanation. What remains then as possible additional causes of differential CPA findings (between the VLCC and containership vessels) are the variables pertaining to scenario conditions.

Table 3-17 presents data regarding non-standard maneuvers (i.e., an evasive action taken by ownship other than an alteration of course to starboard) as a function of ship type. Raw maneuvering data has been included in Appendix D as Tables D-6, D-7, and D-8. The results presented in the tables indicate that twelve VLCC watch officers executed disproportionately more non-standard maneuvers (17) then did six containership officers (2). Further inspection of the data reveals that for those cases in which non-standard maneuvers were used, an overwhelming majority (17 of 19) occurred under scenario conditions of right maneuver

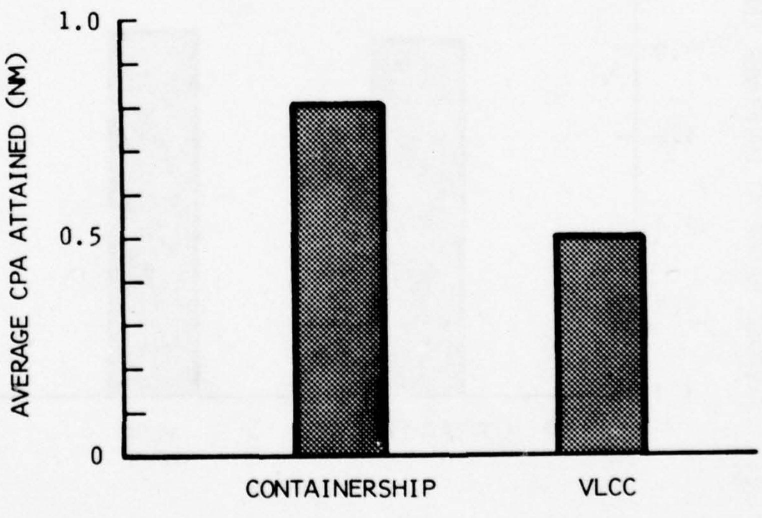

Figure 3-24. Average Attained CPA for Trained VLCC and Containership Groups

restrictions. It can further be inferred from Table 3-17 that maneuvering restrictions had a greater effect on VLCC watch officers than on containership watch officers. The difference between the proportions of non-standard maneuvers for trained VLCC and trained containership officers (29.2 percent vs 4.2 percent) was subjected to a statistical test (Fisher) and found to be significant ($p < 0.03$). The maneuvering data in Appendix D also indicates that the type of restriction had a marked effect on the mariners. Restrictions caused by oil rigs (Watch A) caused more concern than

TABLE 3-17

NON-STANDARD MANEUVERS AS A

FUNCTION OF SHIP TYPE

Ship Type	Conditions	Proportion of Non-Right Maneuvers	Level Of Significance
VLCC (T)	All Runs	7/48	$p = 0.08$*
Containership (T)		2/48	
VLCC (T)	Maneuver Restrictions	7/24	$p < 0.03$*
Containership (T)		1/24	

(Note: Test used was Fisher Test)

* Indicates that results are significant.

those imposed by shallow water (Watch B). That "untrained" VLCC officers, as well as trained VLCC officers, exhibited a substantial percentage of non-standard maneuvers provides further support of the difference between VLCCs and containerships under maneuver restrictions. Therefore, an actual difference was found between ship types for the type of maneuver used under the conditions of maneuver restrictions.

With respect to another scenario consideration, crossing situation, Table 3-16 shows a significant interaction effect ($p < 0.005$) that was found between ship type and crossing situation for CPA attained. It can be seen from Figure 3-25 that the resultant CPA attained by VLCC watch officers is relatively insensitive to the type of crossing situation (clear-cut or ambiguous). However, the resultant CPA achieved by containership watch officers is extremely sensitive to the type of crossing. That is, much closer encounters were experienced/accepted by containership watch officers under ambiguous crossing situations than under clear-cut crossing situations.

With respect to traffic density, a significant way interaction ($p < 0.05$) of ship type, crossing situation, and traffic density was found and is depicted in Figure 3-26. It can be seen that the nature of the significant two-way interaction (ship type and crossing situation, Figure 3-27) differs as a function of a third variable, traffic density.

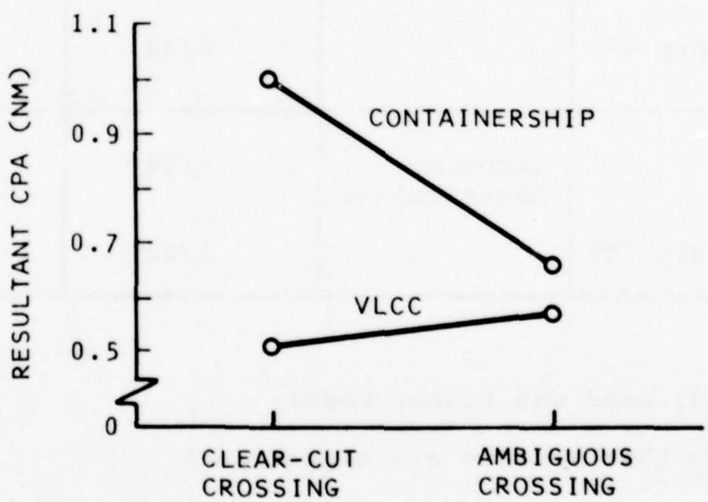

Figure 3-25. Interaction of Ship Type and Crossing Situation - CPA

The resultant CPA attained by containership watch officers, in both low and high vessel traffic, shows a sharp decrease when going from clear-cut to ambiguous crossing situations. With VLCC officers, however, there is a trend reversal in resultant CPA when comparing low to high traffic situations.

Based upon the aforementioned analyses and discussion, it is concluded that the difference in the CPA attained between ship types was a function of both the situations investigated (composed of crossing situation, maneuver restriction and traffic density) and the different handling characteristics of the vessels.

Results of the analyses of variance for the measure of range to the threat vessel at maneuver yielded a significant three-way interaction ($p \approx 0.08$) of ship type, crossing situation and traffic density (Table 3-15). As can be seen in Figure 3-27 the nature of the interaction between ship type and crossing situation differs as a function of traffic density. Further inspection of Figure 3-27 reveals that in heavy traffic situations, there is no interaction between ship type and the type of crossing situation. Under light traffic conditions, however, there is a marked difference.

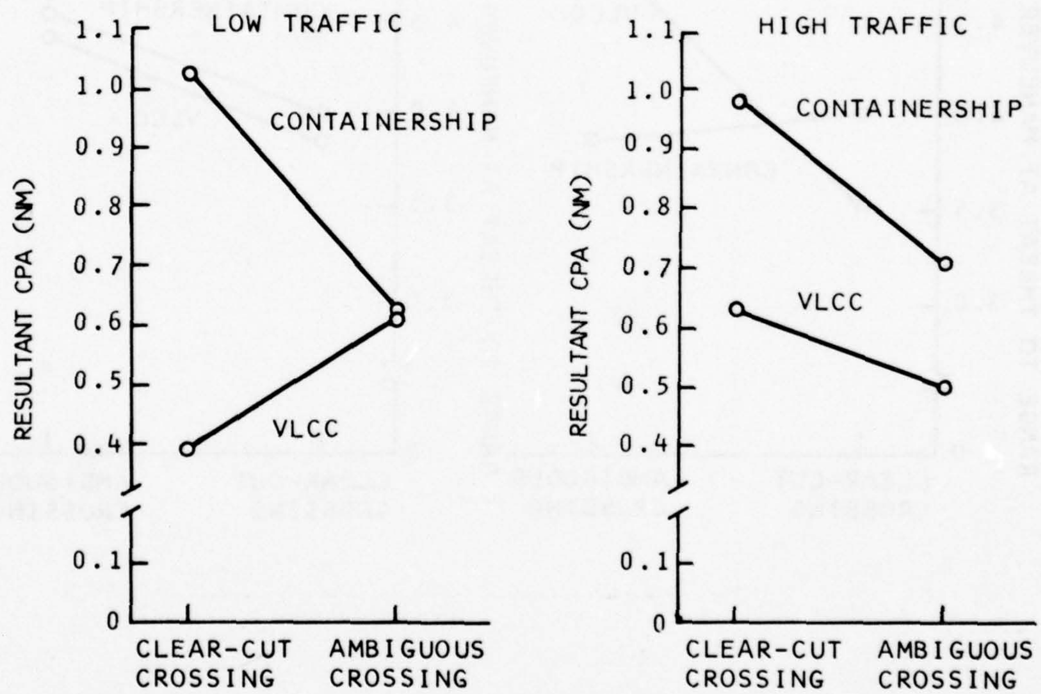

Figure 3-26. Interaction of Ship Type, Crossing Situation and Traffic Density - CPA

With respect to the results attained for container-ship watch officers, a larger average CPA (1.0 nm) was achieved under clear-cut crossing conditions than ambiguous crossings (0.67 hm), as seen in Figure 3-25. This relationship is basically maintained across the two levels of traffic density (Figure 3-26) with a slightly greater spread for low traffic (1.03 - 0.63 nm) than for high traffic (0.98 - 0.71 nm).

It can be seen from Figure 3-27 that for ambiguous crossing situations, containership watch officers maneuvered at a greater range under high traffic conditions (4.5 nm) than low traffic (3.8 nm). However, the magnitude of heading change (Table 3-18) under low traffic was slightly larger (15^{o} vs 17^{o}). Therefore, range at maneuver and the magnitude of the maneuver were compensating to some degree.

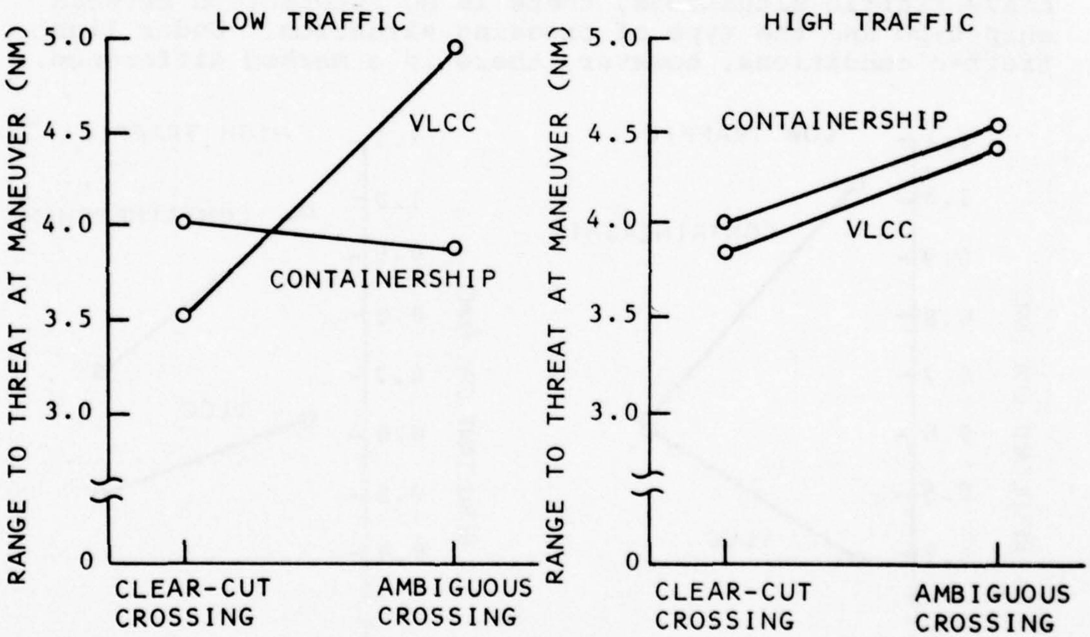

Figure 3-27. Interaction of Ship Type, Crossing Situation and Traffic Density - Range

TABLE 3-18

CONTAINERSHIP (TRAINED) PERFORMANCE

AS A FUNCTION OF SCENARIO CONDITIONS

Measure	Ambiguous Crossing Situations		Clear-Cut Crossing	Ambiguous Crossing
	High Traffic	Low Traffic		
Range At Maneuver (nm)	4.54	3.88	3.99	4.23
Maneuver Magnitude (degrees)	15	17	33	16
Resultant CPA (nm)	0.71	0.61	1.00	0.66

Further inspection of the results presented in Table 3-18 reveals that although containership watch officers maneuvered at approximately the same range, when comparing clear-cut to ambiguous crossing situations, they still achieved a larger CPA under clear-cut crossing situations. The magnitude of the maneuver, however, was slightly more than twice as large for clear-cut crossing conditions (33^{o} see Table 3-18), which would thus account for the larger CPA achieved.

Regarding VLCC watch officer performance, approximately the same CPA was achieved when comparing clear-cut crossing situations to ambiguous crossings (Figure 3-25 and Table 3-19). Comparing ambiguous to clear-cut crossings, it can be seen from Table 3-19 that VLCC officers maneuvered at a greater range under ambiguous crossing situations (4.66 nm), but the magnitude of maneuver was much less (35^{o}). Therefore, the VLCC watch officers who had small potential CPAs available to them bacause of their ship's handling characteristics, appeared to take advantage of the changes rule 14c in the ambiguous crossing situation and maneuvered earlier than in the clear-cut case, based on a "head-on decision." The magnitude of the maneuver (course change) was smaller at the longer range, however, resulting in approximately the same CPA (0.50 nm vs 0.57 nm) for the two types of crossing situations. Furthermore, VLCC watch officers maneuvered at a slightly larger range in low traffic and achieved a smaller CPA (Table 3-19). Inspection of the results in the table for crossing by traffic combinations reveals that, on the average, the VLCC officers executed maneuvers at longer ranges for the ambiguous crossing situations (4.95 nm and 4.40 nm) compared with the clear-cut situations (3.52 nm and 3.85 nm). This occurred with smaller maneuver magnitudes, 37^{o} and 32^{o} compared with 73^{o} and 59^{o}. Yet a differential effect was found in attained CPA; for high traffic the ambiguous crossing CPA was smaller than the clear-cut crossing CPA, but the reverse was true with low traffic situations.

The high traffic performance follows the expected pattern; maneuvering at a greater range for ambiguous crossing conditions in accordance with Rule 14c and anticipating (and attaining) a smaller CPA for the fine "head-on" situation compared with a broader crossing. The maneuver magnitude results also fit this pattern since a smaller maneuver is normally used with the finer (more head-on) encounter geometry than with the clear-cut crossing situation.

Performance by the VLCC watch officers also appears to follow the pattern regarding range and maneuver magnitude for low traffic condition, but breaks down in the area of

TABLE 3-19

VLCC (TRAINED) PERFORMANCE AS A FUNCTION OF SCENARIO CONDITIONS

Measure	Crossing		Traffic		Low Traffic		High Traffic	
	Cl-Cut[a]	Ambig[b]	Low	High	Cl-Cut[a]	Ambig[b]	Cl-Cut[a]	Ambig[b]
Range At Maneuver (nm)	3.68	4.66	4.20	4.13	3.52	4.95	3.85	4.40
Maneuver Magnitude (deg.)	66	35	55	45	73	37	59	32
Resultant CPA (nm)	0.51	0.57	0.51	0.57	0.39	0.64	0.63	0.50

[a] Clear-cut crossing (25°)

[b] Ambiguous crossing (5°)

CPA. The attained CPA for the clear-cut crossing geometry was found to be not only smaller than for the ambiguous crossing situation, but the size of average attained CPA was quite small on an absolute basis (0.39 nm). This anomaly is most probably caused by the maneuvering characteristics of a VLCC itself. The larger average maneuver magnitude of 73° (which is close to the "best" course change possible, see Table 3-19) does not fully compensate for the difference in range at which the maneuvers occur (3.25 nm vs 4.85 nm), and therefore there is a sharp degradation in attained CPA.

3.2.2.2.2 Pooled Effects

Statistically significant effects ($p < 0.05$) were also derived from the ship type analyses of variance for the three variables of crossing situation, maneuver restriction, and traffic density when the comparisons were made within the subject variables using the total trained group findings (both VLCC and containership mariners) as the basis of the analyses. The results of the analyses for range at maneuver and attained CPA are presented in Tables 3-20 and 3-21.

TABLE 3-20

SUMMARY OF SIGNIFICANT EFFECTS FROM ANALYSIS OF VARIANCE - RANGE AT MANEUVER - SHIP TYPE DESIGN

Effects	F Ratio	Degrees of Freedom
Crossing Situation	6.37*	1, 5

* $p \approx 0.05$

Significant main effects for the crossing situation variable are indicated for both range and CPA attained.

It can be seen from Figure 3-28 that in the ship type design, the average CPA was greater for clear-cut crossing situations (0.76 nm) than ambiguous crossings (0.61 nm) and that this difference was significant ($p < 0.01$, Table 3-21). In addition, range at maneuver was smaller for clear-cut crossings (3.83 nm) than for ambiguous crossings (4.40 nm) (see Figure 3-29) and was significant ($p = 0.5$, Table 3-20).

That the type of crossing situation resulted in a significantly different CPA attained can be attributed to the magnitude of the maneuver (see Table 3-22). In comparing

TABLE 3-21

SUMMARY OF SIGNIFICANT EFFECTS FROM ANALYSIS OF VARIANCE - CPA ATTAINED - SHIP TYPE DESIGN

Effects	F Ratio	Degrees of Freedom
Crossing Situation	17.38*	1,5
Maneuver Restriction X Crossing Situation X Traffic Density	7.98**	1,5

*p <0.01
**p <0.05

the two types of crossing situations (clear-cut and ambiguous) with respect to the magnitude of maneuvers (i.e., the heading changes commanded and attained), a marked difference was found between the average heading change in clear-cut crossing situations (50°) and ambiguous crossing situations (25°). Thus, as can be seen in Table 3-22, watch officers (both VLCC and containership) under clear-cut situations 1) maneuvered at a smaller range, but 2) executed much larger maneuvers and achieved a larger average CPA. Thus, the magnitude of the maneuver overcompensated for the range at maneuver under clear-cut crossing situations, yielding a larger CPA. Furthermore, the results of this investigation corroborates those of a previous experiment study (Cooper, Carey, and Mara, 1970) that small angles of approach (fine on the bow) are the most difficult for watch officers to handle.

It should be noted that these results are based on the pooling of the contributions of the trained VLCC and the trained containership findings to all of the parameter averages and though the absolute values are thereby confounded, the trend due to the two levels of a given variable is not. For example, it has been indicated that a 30° maneuver magnitude by a VLCC watch officer does not have the

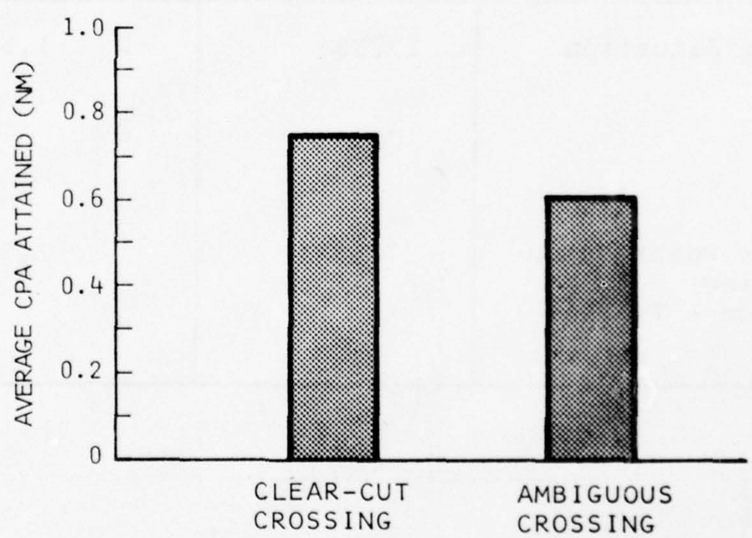

Figure 3-28. Average Attained CPA as a Function of Crossing Situation - Ship Type Design

same absolute CPA effect as a 30° maneuver magnitude for a containership master. But, a change of 25° to 50° does increase the potential available CPAs in both cases and, therefore, an increasing CPA observation can be made even when the ship effects are averaged.

That the type of crossing situation resulted in a significantly different range at maneuver (4.40 nm for ambiguous crossings and 3.83 nm for clear-cut crossings) appears to be due to the Rules of the Road. In ambiguous crossings, in which it is questionable as to whether the situation is head-on or not, it appears that the watch officer interprets these situations as head-on and thus does not have stand-on vessel obligations. This practice, in fact, has been delineated by the Revised International Rules of the Road, specifically, Rule 14c which states, "When a vessel is in any doubt as to whether such a situation (head-on) exists, she shall assume that it does exist and act accordingly."

For the variable of traffic density and maneuver restriction, the ship type analyses of variance did not yield any main effects for the dependent measures of range at maneuver or resultant CPA. However, a significant interaction effect for CPA was found between traffic density, maneuver restriction and crossing situation, as indicated in Table 3-21. It

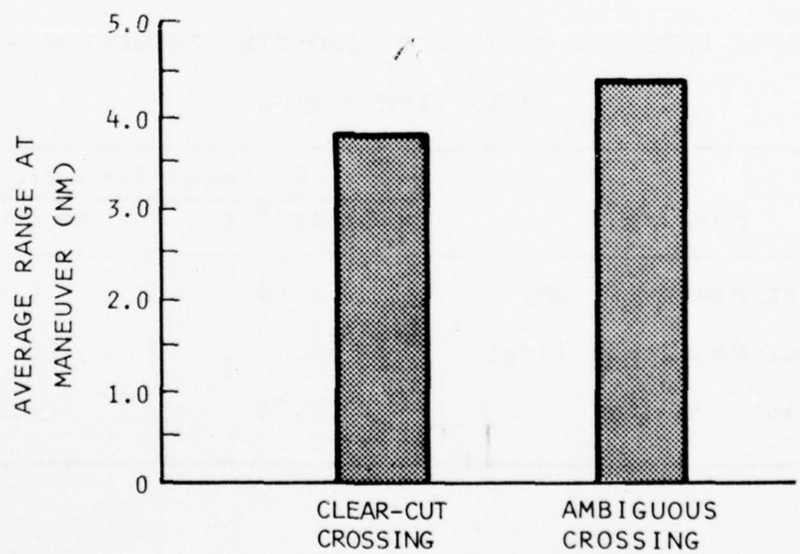

Figure 3-29. Average Range at Maneuver as a Function of Crossing Situation - Ship Type Design

can be seen from Figure 3-30 that the resultant achieved CPA for the clear-cut crossing situation in both low and high vessel traffic is relatively constant with "no restriction" scenarios, but shows an increasing trend, from low to high traffic, when restrictions on the right are present. In the ambiguous crossing, no restrictions situation, the attained CPA is relatively independent of traffic density (a difference of approximately 0.1 nm) but shows a decreasing trend, from low to high traffic when restrictions on the right are present.

Table 3-23 indicates the overall performance of range, maneuver magnitude, and CPA with the ship type design. There is a consistent increase in maneuvering range when ambiguous crossing situations are compared with clear-cut crossing encounters in each of the four permutations of the other variables (e.g., 2.90 nm to 4.55 nm for the restriction and low traffic encounters). Maneuvering magnitude increases under the same comparisons and attained CPA increases in all of the cases except the restriction/low traffic situation, where it is essentially constant (0.63 nm compared with 0.59 nm).

TABLE 3-22

TRAINED VLCC AND TRAINED CONTAINERSHIP PERFORMANCE

AS A FUNCTION OF TYPE OF CROSSING SITUATION -

SHIP TYPE DESIGN

Measure	Crossing Situation	
	Clear-Cut	Ambiguous
Range at Maneuver (nm)	3.84	4.44
Maneuver Magnitude (deg)	50	25
Resultant CPA (nm)	0.76	0.61

These results show that the mariners took advantage of Rule 14c to maneuver earlier for ambiguous crossing situations, accepted equal or smaller CPA's for the finer encounter geometries, and adjusted their performances to the more acceptable smaller maneuver in the near head-on situation. The smallest CPA was obtained under the ambiguous crossing, high traffic, restricted scenarios condition, which occurred with the earliest point of maneuver (4.66 nm). This combination of variables had been expected to cause the greatest concern to the mariners and, based on the size of the average CPA, it did. Under the clear-cut crossing, high traffic, restricted scenario situation, the greater average maneuvering magnitude resulted in a substantially larger CPA even though the maneuvering range decreased somewhat (from 4.66 nm to 4.03 nm).

3.2.2.3 Summary Discussion

The ship type experiment design was established to determine whether or not a difference in behavior existed between watch officers of substantially different classes of ships while operating under the new Rules of the Road in stand-on vessel encounters. Comparisons were made between mariners

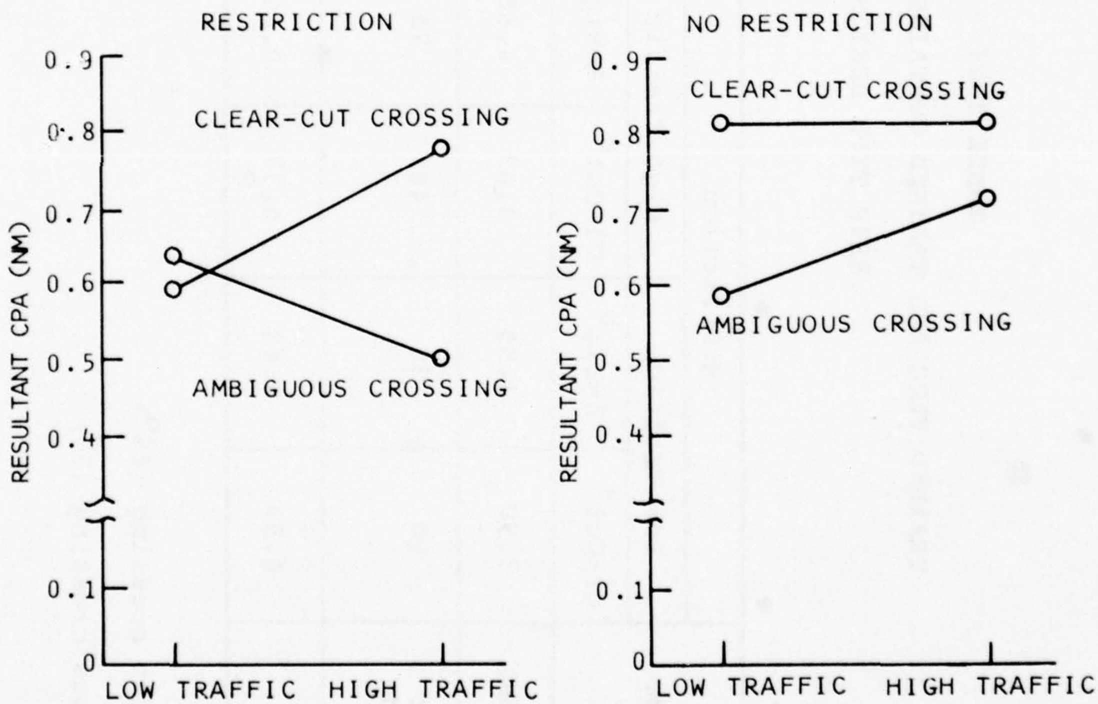

Figure 3-30. Interaction of Crossing Situation, Traffic Density, and Maneuver Restriction - CPA

TABLE 3-23

TRAINED VLCC AND TRAINED CONTAINERSHIP PERFORMANCE - SHIP TYPE DESIGN

Measure	Restriction				No Restriction			
	Low Traffic		High Traffic		Low Traffic		High Traffic	
	Cl-Cut[a]	Ambig[b]	Cl-Cut[a]	Ambig[b]	Cl-Cut[a]	Ambig[b]	Cl-Cut[a]	Ambig[b]
Range (nm)	3.90	4.55	4.03	4.66	3.63	4.25	3.79	4.27
Maneuver Magnitude (Deg)	60	30	44	28	62	24	49	25
CPA (nm)	0.59	0.63	0.77	0.50	0.83	0.59	0.83	0.71

[a] Clear-Cut crossing (25^{o})

[b] Ambiguous crossing (5^{o})

experienced with, and conning, large ponderous VLCC vessels (250,000 DWT), and those experienced with, and conning, fast maneuverable containerships. Both groups were trained in the changes to the rules.

Significant differences in bridge behavior of the two groups were observed. These differences appeared in the areas of attained CPAs, handling of clear-cut crossing vs ambiguous crossing situations and differences related to encounters containing maneuvering restrictions to starboard (but with adequate maneuvering room).

There was a significant difference between the attained CPA for the two subject groupings. The VLCC watch officers maneuvered at approximately the same average range as did the containership mariners (4 nm), but they obtained a smaller average CPA.

As a consequence of these striking results, additional analyses were performed to investigate the CPAs available to both types of vessels. These analyses showed that the containership mariners had a large potential CPA available to them because of their vessel's characteristics. They were therefore capable of attaining practically any CPA that they wanted. Alternatively, the VLCC mariners had a small CPA available to them and were severely limited by their vessel's characteristics. These analyses were conducted for a 4 nm maneuvering range since this was the average range found for both groups during the investigation. If the VLCC officers had maneuvered earlier, they too could have obtained a larger reserve CPA but they appeared to be constrained to the same range as the containership mariners. In fact, the actual average range at maneuver for more than half of the VLCC watch officers was close to the range that they had expressed as desireable for a stand-on vessel.

Part of the reason for this constraint can be found in the marine literature. Associated with this investigation, a literature search was conducted and the recommended range for a stand-on vessel maneuver was found to be 2-1/2 to 4-1/2 miles, dependent on "circumstances." The potential outer limit for legal interpretation under the new rules was set at 5 nm. The analyses have indicated that this does not yield a large potential CPA for a VLCC vessel in a high closing rate situation. Another possibility for the constraint may be related to the background experience of the VLCC watch officers. Any watch stander in a stand-on situation is waiting for the other vessel to maneuver and his decision-making process (determination that he himself should maneuver) is one of increasing pressure and stress as

the distance to the threat vessel narrows. The literature indicates (Filts, P.M.) that under stress conditions, behavior reverts to previously learned experiences. These VLCC mariners were previously on smaller, more maneuverable vessels earlier in their careers, where 4 nm maneuvering was acceptable. Also, at what point should a give-way vessel maneuver? Five to six miles is a normal expectation and therefore something smaller than that would be the maneuvering range of the stand-on vessel.

Therefore a combination of the marine literature, Rules of the Road, and previous experience all indicate to the watch officers that a 4 nm maneuvering range is acceptable. Analyses have shown that this results in CPAs which are smaller than the VLCC mariners themselves desire.

Additional behavioral differences between the VLCC and containership mariners were found. It was expected that mariners would take advantage of the new rule regarding near head-on situations (Rule 14c) and maneuver earlier under ambiguous crossing situations compared with clear-cut crossing encounters. With these near head-on conditions, smaller maneuvers were anticipated (because of situation geometry) and, in accordance with previous practice, smaller CPAs should have been accepted by the watch officers.

This type of performance behavior did occur with both types of mariners under the pressure of high traffic scenario conditions. Although the maneuvering ranges were somewhat smaller for VLCC watch officers than for containership watch officers, the maneuver magnitudes and attained CPAs did follow the expected pattern, with resultant CPAs for the VLCC vessels being considerably smaller than those obtained for containerships.

Under the low traffic conditions, the containership mariners maneuvered at approximately the same range for the two types of crossing encounters (somewhat less for ambiguous crossings), using the smaller maneuvers and obtaining smaller CPAs for ambiguous crossings. The VLCC officers maneuvered at a fairly large average range for low traffic ambiguous crossing conditions, but with clear-cut encounters and low traffic, they maneuvered late, that is, at a close range. Once the maneuver was executed, they observed the developing situation and continued their turn until a substantial course change had been achieved. This combination of low range and large maneuvering angle still resulted in a fairly small attained CPA. This again reflects the maneuverability and ship handling characteristics of the larger vessel which was discussed previously.

The restriction on the right had a marked effect on the VLCC mariners compared with containership mariners. From the training experiment design, a significant difference between maneuvering range for restricted encounters compared to encounters with no restrictions was observed for all of the VLCC watch officers. Maneuvers to starboard have historically been associated with good seamanship and are recommended by the Rules of the Road; therefore departure from this behavior for collision avoidance purposes is a reflection of the watch officer's concern with a pressured situation. In this regard substantially more non-standard maneuvers (alterations of course to port, or speed changes) were made by VLCC watch officers compared with containership officers. They also exhibited more concern with oil rigs and remaining within the safety fairways (in the Gulf of Mexico watch) than with the shallow water restrictions in the Florida Strait watch.

3.3 GENERALIZED CONSIDERATIONS

The previous subsections within Chapter 3 have been concerned primarily with the major objectives of the Rules of the Road Training Investigation, and the organization of Chapter 3 has compartmentalized the discussions, up to this point, along the lines of the two basic portions of the experiment design (i.e., training vs no-training and ship class - VLCC vs containership). The previous approach has also been mainly statistical in nature, relying heavily on several different types of numerical analyses and tests. As a consequence of this type of investigation, it is not uncommon to find concepts or conditions that cut across all of the experiment objectives, considerations that do not lend themselves completely to statistical analyses, or interesting connotations which are subjective and/or speculative in nature. This subsection of Generalized Considerations is therefore presented in an attempt to group these types of comments and thereby complete the presentation of all of the findings.

3.3.1 Previous Findings

The general applicability of the findings resulting from this experiment is dependent on the developed scenario situations, the representativeness of the subject sample, and the validity of CAORF, among other factors. The applicability of findings, as well as their reliability, may be demonstrated by comparing the results with results of similar investigations. The discussion pertaining to the probability of the stand-on vessel maneuver demonstrated substantial agreement between the maneuver ranges obtained in this experiment and those found in the literature. In

this regard, a comparison was made between the CPAs obtained in this experiment and those resulting from an earlier CAORF study. That study had been conducted on CAORF to investigate the effect of various levels of electronic aiding: visual only, visual plus radar, and visual plus radar plus collision avoidance system. The study was performed under the old rules. One of the scenarios used during that investigation was similar to watch segment A2 in the present experiment. The obtained CPAs in both studies are summarized in Table 3-24. Inspection of this table shows that the VLCC no-training group achieved CPAs similar to those of an 80,000 DWT tanker in the earlier study. Comparison with the VLCC training group shows a slightly higher average CPA and no collisions, as would be expected. Comparison with the containership (training) group shows still greater differences, as expected. These findings demonstrate consistency between the current and earlier studies.

3.3.2 Maneuver Restrictions

The eight scenarios were balanced with regard to the within-subject variable of restriction on the right, with four scenarios having restrictions and four having none. The watches in turn were also balanced with each of the two 4-hour watches having two restricted segments and two no-restriction segments. One of the measures that was utilized to analyze the performance of the watch officers was the type of maneuver used to avoid a collision with the non-maneuvering give-way prime target ship. The new rules strongly indicate that a maneuver to starboard is most desirable (required, if circumstances permit) so that a turn to starboard could really be thought of as a "standard" maneuver and a turn to port or a decrease in speed appears to be the maneuver of exception, or stress, or one of a "non-standard" variety.

The previous sections of this report have shown that the frequency of non-right maneuvers during the experiment runs indicated a correlation with ship class (i.e., the VLCC maneuvers contributing 17 of the 19 incidents and the containership watch officers accounting for the remaining 2).

An alternate evaluation of the frequency of non-right maneuvers shows that 17 of the 19 incidents occurred across all subjects during the restricted scenarios, and 2 took place during no-restriction encounters.

TABLE 3-24

COMPARISON OF CPAs BETWEEN CURRENT AND

EARLIER CAORF STUDIES

Study	Scenario	Group	Obtained CPA Limits (nm)	Average CPA (nm)
Earlier CAORF	#10	Untrained 80,000 DWT Tanker	0 to 0.7	0.3
Current CAORF	A2	Untrained VLCC	0 to 0.7	0.35
		Trained VLCC	0.2 to 0.6	0.4
		Trained Containership	0.3 to 0.8	0.57

Yet a third look at the breakdown of findings yields the fact that of the 17 occurrences of non-standard maneuvers on restricted runs (obviously situations that caused the mariners to deviate from "normal" behavior), 14 of the situations occurred in Watch A and 3 took place in Watch B. The maneuver restrictions in Watch A were oil rigs on the right side of the fairway, while the B watch had shoal water on the right.

All of the foregoing data presents an interesting picture which emerged from the experiment findings; namely, the VLCC watch officers had the largest concern (inferred from the non-standard behavior) with the scenarios containing restrictions on the right, and these deep draft vessel mariners were more concerned with oil rigs and safety fairways than with shoal water. Whether these mariners' deeper respect for oil rigs is due to the fact they that are accustomed to the dangers of shoals, or they have more concern for the possibility of capped underwater wells which do not appear on navigational charts or some other unidentified reason, is not known. These findings, therefore, also present an interesting area for further investigation.

3.3.3 Estimations

One hundred and forty-four experiment runs were completed at CAORF for the Rules of the Road Training Investigation. Of these runs, 141 yielded data which followed the basic experiment design and three runs were outside of these aims. Estimated values of range to target at maneuver and attained CPA were generated and used for these three runs.

The three sets of estimated values fall into two basic categories; run A3V for subject 058 and A3C for subject 063 comprise one category and run A3V for subject 059 is the second category.

The first category consists of occasions in which the watch officer maneuvered for both the chaff target and the primary target, but the maneuver for the chaff target "spoiled" the geometry intended for the primary target encounter. There were other runs (11 in number) in which the subject maneuvering for the chaff target did not appreciably change the encounter geometry for the following prime target, and the data for those 11 runs were used in the analyses. It was felt though, that the conditions of the two runs in the first category were sufficiently changed from the conditions of the basic design so as to invalidate the resulting data.

The run in the second category had a maneuver which appeared highly questionable (i.e., very early in the run). During the debriefing after that run, the subject (059) indicated that he had maneuvered because of the depth of water (108 feet), not the target ship. It became apparent during the discussion that the VLCC master had erred, since he indicated that his vessel (65 foot draft) would normally need 15 feet of clearance under the keel for "safety," or 80 feet total. He had an additional clearance of 28 feet during this run. The data was therefore also considered invalid.

As indicated above, in order to perform analyses of variance for the measures of range at maneuver and CPA based on equal cell size, values of range and CPA were estimated (three of each). The estimations were based upon the following equation (Myers, 1972).

$$X_{ij} = \frac{rT_i + cT_j - T}{(r-1)(c-1)}$$

where:

X_{ij}	=	estimate of the missing value
r	=	number of rows in the matrix
T_i	=	sum of scores for row containing missing value
c	=	number of columns in the matrix
T_j	=	sum of scores for column containing missing value
T	=	total sum of scores

Furthermore, one df (degree of freedom) was subtracted from the error term df for each value estimated.

A test for heterogeneity of variance (Hartley, 1950) was performed on the data, and the homogeneity of variance assumption was found to be untenable. In accordance with Myers (1972) therefore, it was assumed that the worst possible degree of heterogeneity of variances and covariances existed, and the F statistics were assessed against the F required for significance based upon 1 and (n-1)df. Thus, if an obtained F is significant with this conservative approach, we can have reasonable faith in our rejection of the null hypothesis.

3.3.4 Collisions and Near Misses

In a ten-week period, each of the 18 subjects ran through the eight experiment runs for a total of 144 stand-on vessel encounters with give-way ships that violate the Rules of the Road. This compression in time of real world situations represents a sizeable analysis of one dangerous

segment of the total compass possibilities; i.e., the fine port crossing and meeting situation. The reference to time compression is of course relevant to the fact that it might take months or even years to accumulate this type of experience on the open seas, as opposed to the controlled environment of a simulator. It is difficult to determine what miss distance would be desired or accepted by most practical navigators for themselves or from subordinates, but it is fairly certain that a vast majority would indicate that less than one ship length is "too close for comfort," especially under clear, ideal environmental conditions. Five out of 144 or 3.5 percent of the experiment runs resulted in a miss distance (CPA) of under 1000 feet, with two of these five (1.4 percent of 144) being actual collisions. Each of these five incidents occurred during different watch segments with three of them in the Gulf watch and two in the Florida Straits watch. Two of the segments were in clear-cut crossing situations while three were of the ambiguous crossing variety. All five incidents occurred with VLCC watch officers with one of them "trained" and the others "untrained." In all, a total of four watch officers were involved in these incidents.

Figures 3-31 through 3-35 are computer generated plots in the vicinity of the closest point of approach for each of the incidents. The ships are shown at 30-second intervals and, in three of these plots, interpolations of ship position close to the CPA or collision point were added.

For purposes of clarity the ships have been identified by a number of lines near the bow and on any one plot an equivalent number of lines (say 3) on one bow and the same number (3) on another bow show that these two ship positions represent the same point in time. The maneuvering ship is always ownship. It should be also noted that the rudder angle is shown by means of a rudder drawn at the correct angle but larger than scale, for clarity.

3.3.4.1 Collision No. 1 (Figure 3-31)

Summary:

Subject - #74
- VLCC untrained
- U.S. national

Watch Segment - A2V
- Gulf, restriction, high traffic density, ambiguous crossing situation
- Test subject's assessment: head-on situation
- Sixth run on simulator (2 PM)
- Last experience in actual area: 1974

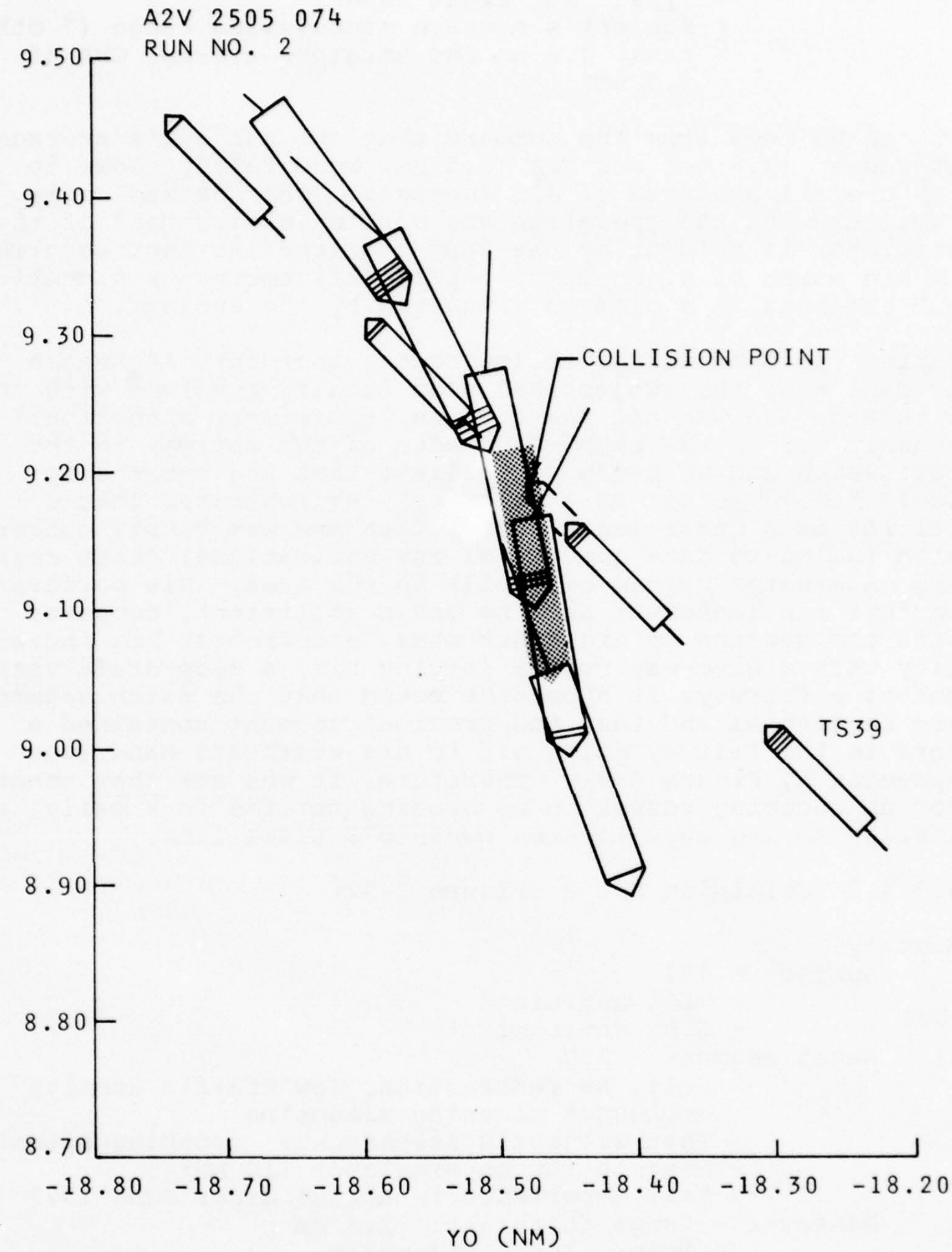

Figure 3-31. Collision #1

Maneuver - Range to target: 1 nm
- Type: 20° right rudder
- Subject's average maneuvering range (7 other runs) 3.6 nm and attained average CPA of 0.5 nm

It can be seen from the summary that the subject's averages of range (3.6 nm) and CPA (0.5 nm) were fairly close to the overall averages of all subjects. That he was quite familiar with the operation and working environment of the simulator is evident by the fact that the incident occurred on his sixth of eight runs. Also, this ambiguous situation was assessed as a head-on situation by the subject.

During the debriefings following the incident, it became evident that the subject had been totally involved with the situation and was not aware of an "experiment situation." Ownship was on the right-hand edge of the fairway in the Gulf watch and he could not believe that the other ship would "crowd me out of a fairway." He indicated that a fairway is a quasi-legal restriction and was deeply concerned with the up-to-date quality of any navigational chart regarding underwater capped oil wells in the area. His performance on this run (maneuver at 1 nm and a collision), compared with the average on his other runs, underscores his incredulity with a give-way vessel forcing him, a deep-draft vessel, out of a fairway. It should be noted that the watch segments are sequential and that the previous segment contained a fork in the fairway going off to his starboard hand (see Appendix A, Figure A-2). Therefore, it was not that unnatural for an oncoming vessel to be heading for the fork early, and thereby moving over towards ownship's track line.

3.3.4.2 Collision No. 2 (Figure 3-32)

Summary:

Subject - #71
- VLCC untrained
- U.S. national

Watch Segment - A3V
- Gulf, no restriction, low traffic density ambiguous crossing situation
- Test subject's assessment: crossing situation
- Seventh run on simulator (10 AM)
- Last experience in actual area; June 1977

Maneuver - Range to target: 2.6 nm
- Type: Speed reduction
- Subject's average maneuvering range (7 other runs) 2.6 nm and attained average CPA of 0.2 nm

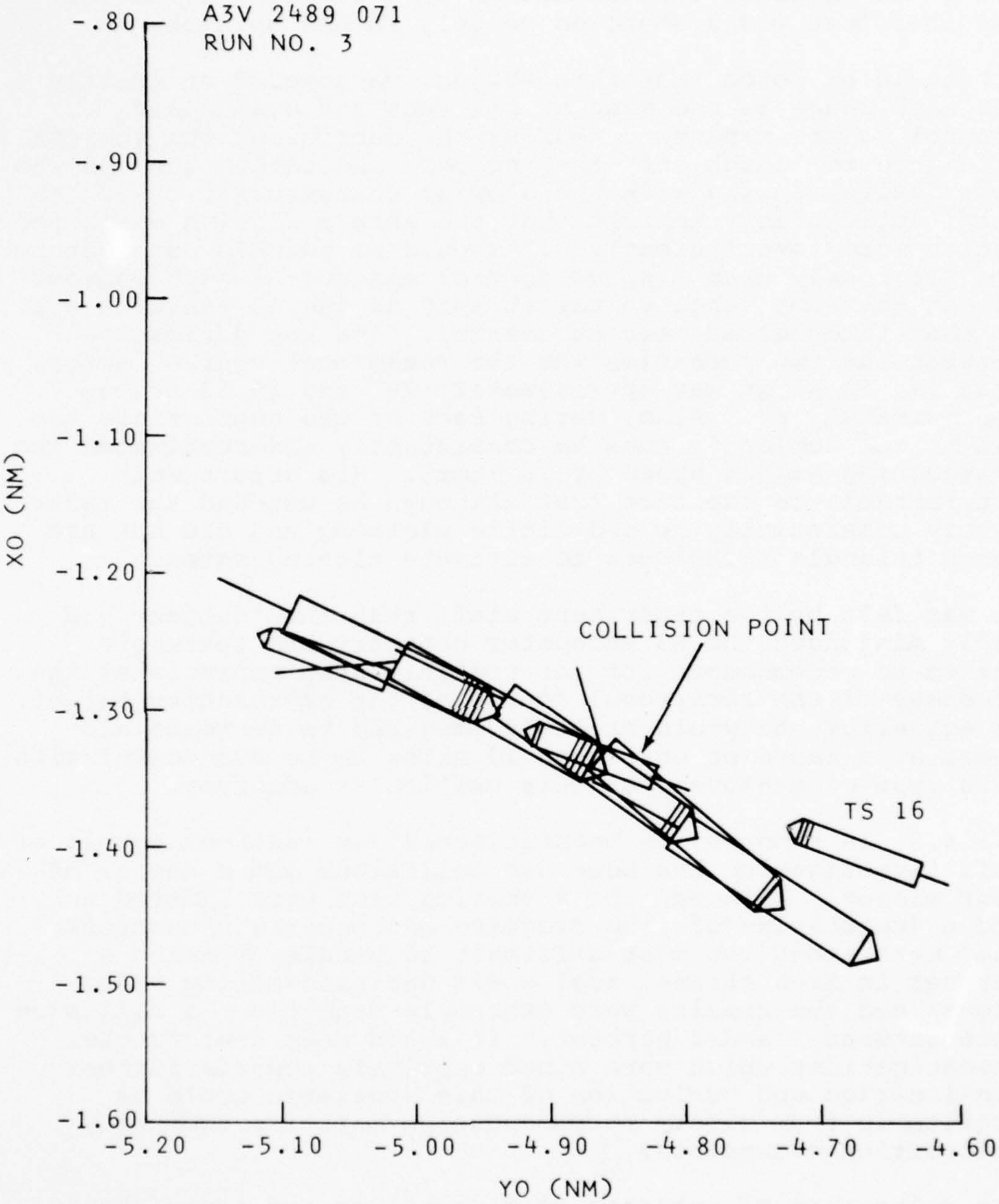

Figure 3-32. Collision #2

It can be seen from the summary that the subject's average range of maneuver (2.6 nm) and CPA (0.2 nm) were close to the lower ranges for all subjects. He was quite familiar with the simulator (seventh run) at the time of the incident. He assessed this situation as a crossing situation and therefore was a stand-on vessel, in his opinion.

It should be noted that this subject maneuvered at exactly the same range as the mean of his runs and used speed control as his maneuver. During the debriefing the subject attempted to "laugh off" the incident indicating that he was just "experimenting with the slowing characteristics of the ship" (predictably he felt that the ship's slowing characteristics were insufficient). It should be pointed out that he had previously used a speed control maneuver (watch segment A1) at the same range to target ship as the A3 maneuver and at that time he had been successful. The key difference between the two scenarios was the reciprocal course factor, that is, in A1 it was approximately 20° and in A3 it was approximately 6°. Also, during each of the debriefings for all of the subject's runs he consistently underestimated the approaching target speed by 10 knots. His errors were attributable to the fact that although he watched the radar fairly consistently he did little plotting and did not use speed triangle techniques to estimate closing rates.

It was felt by the experiment staff that this subject had badly misjudged the A3 encounter geometry and therefore failed to accommodate for (or possibly even appreciate) the fineness of the reciprocal course of the approaching target. In actuality, he would probably have had to decrease his speed at a range of more than 10 miles to be successful with this type of maneuver for this particular scenario.

3.3.4.3 In summary, an unanticipated and indirect result of this investigation has been two collisions and a number of near misses. Although the scenarios used were limited in scope (consisting of fine crossing and meeting situations) they were among the most difficult to handle, placing a mariner in high stress, real world decision-making situations; and the results were extremely dramatic - a collision rate between 1 and 2 percent. It would seem that further investigations which were aimed expressly towards further confirmation and evaluation of this statistic could be profitable from safety recommendation/maritime community information viewpoints.

The reluctance of subjects to depart from a fairway should also be underscored. In addition to the comments received regarding Collision No. 1, several debriefing observations

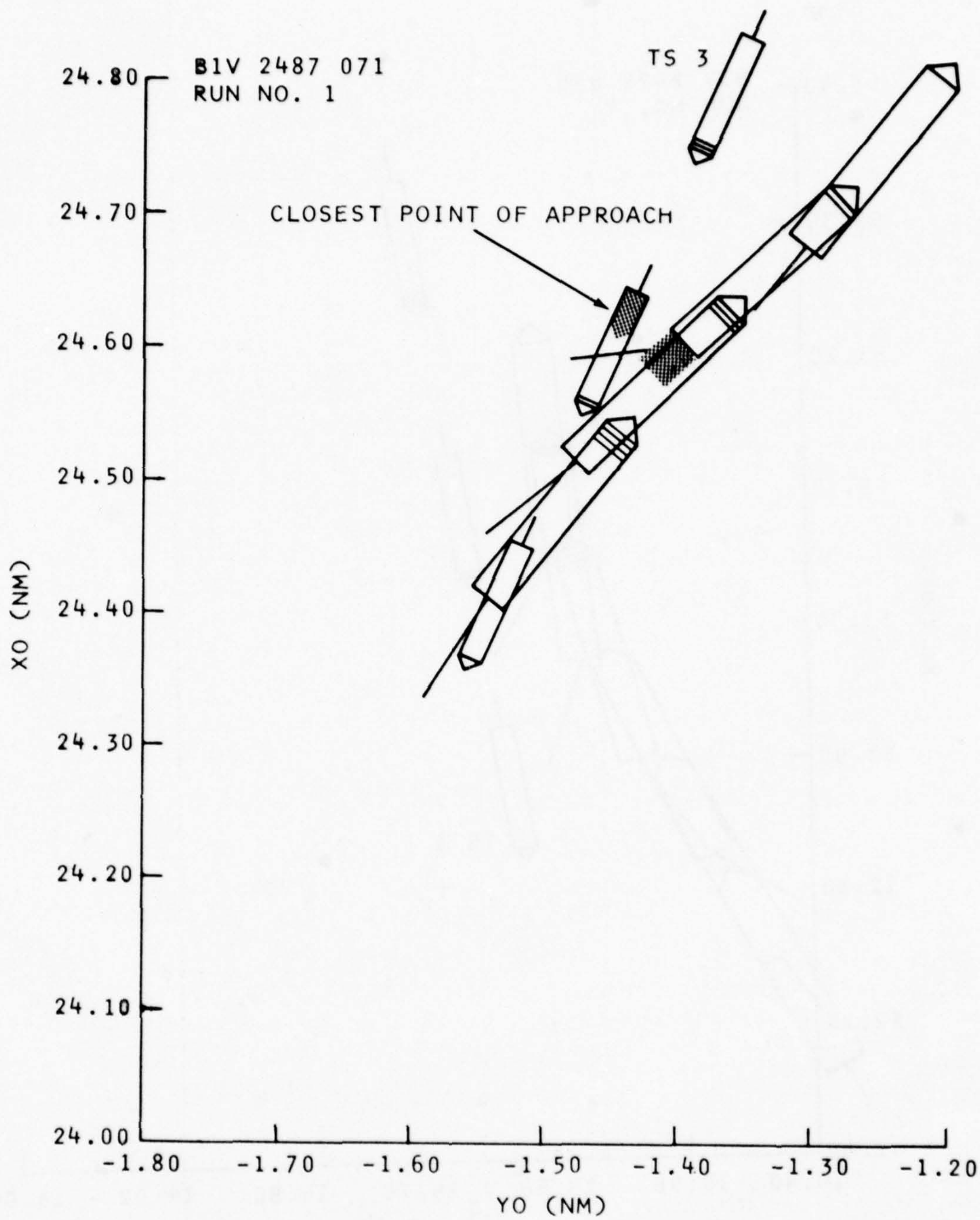

Figure 3-33. Near Miss #1

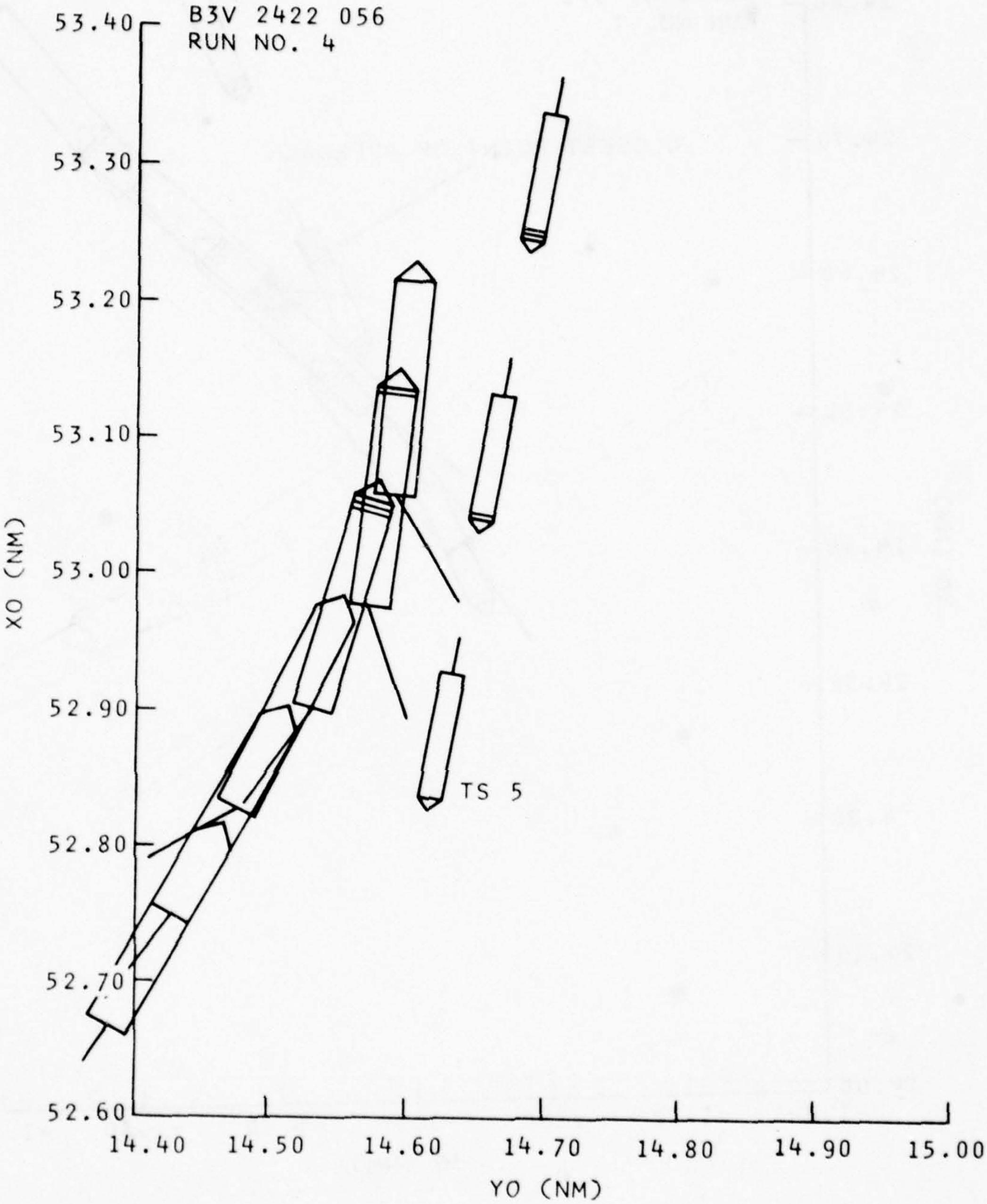

Figure 3-34. Near Miss # 2

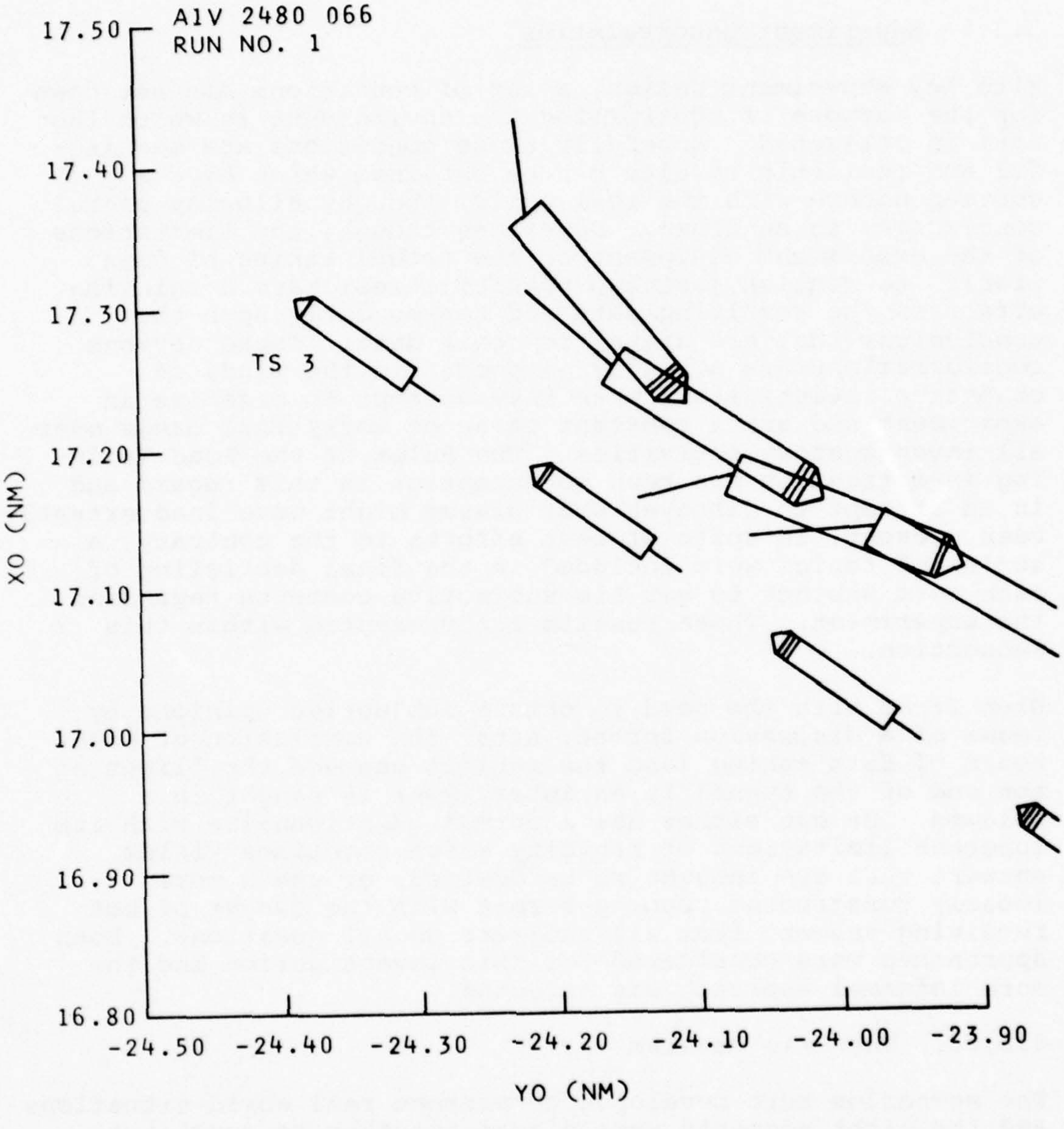

Figure 3-35. Near Miss #3

were made relative to the "uneasiness" felt by mariners when directed to "cut the corner" of the fairways on the A3 Gulf watch segment. This occurred with several VLCC and containership masters and may very well represent a generalized concept, rather than one restricted solely to deep-draft vessels.

3.3.5 Experiment Uncertainties

With any experiment design, a set of conditions are set down for the purpose of controlling the environment in which the data is collected. Hopefully these conditions are meaningful and realistic results can be obtained which have a correspondence with the real world, thereby allowing useful conclusions to be drawn. Sometimes though, the limitations of the experiment equipment or the actual taking of data itself (to mention just two possibilities) have a tainting effect on the resulting data and consequently upon the conclusions that are drawn from this data. These obvious considerations are normally paramount in the minds of objective investigators when they attempt to organize an experiment and are a constant cause of worry that hangs over all investigatory activities. The Rules of the Road Training Investigation has been no exception in this regard and in an attempt to discover what biases might have inadvertently been present, in spite of best efforts to the contrary, a series of topics were included in the final debriefing of each test subject to get his subjective comments regarding the experiment. These results are presented within this subsection.

When faced with the need to obtain subjective opinions by means of a discussion format, after the conclusion of eight hours of data taking (and the subject can see the "light at the end of the tunnel"), an interviewer is caught in a dilemma. He can either use a formal questionnaire with its inherent limitations of rigidity which sometimes yields answers that are thought to be desired, or use a more loosely constructed probing format with the danger of not receiving answers from all subjects on all questions. Both approaches were considered for this investigation and the more informal approach was selected.

3.3.5.1 Scenario Realism

The scenarios were developed to present real world situations and the eight segments were placed together to constitute two four-hour watches, one which takes place in the Gulf of Mexico and the other in the Florida Straits. The action and type of vessels in the vicinity of ownship were predicated on what might be expected in the particular location involved.

The high traffic density scenarios were adapted from actual situations that occurred at sea. The at-sea situations were reconstructed from an extensive file of actual at-sea encounters containing ownship and other ship information.

One of the topic areas discussed with the subjects at the final debriefings was the realism of these scenarios. Of the 14 answers that were obtained, 13 of the mariners thought that the runs were realistic and normal for the areas. Only one of the watch officers felt that the scenario situations were more difficult than are normally encountered. This mariner was a foreign national and had not been in either of the two watch areas previously.

Regarding the experience factor with the Gulf and the Florida Straits, 14 of the 18 subjects had sailed in the areas before, in fact most had been there as recently as 1974 (within the past 3 years). The conclusions that can be drawn from these analyses are that the scenarios themselves did not present a learning situation and that the mariners were not reacting to an "artificial" quality of the simulator runs. In fact, the findings of the CAORF validation study (Hammell 1976) have previously demonstrated the similarity between mate behavior on CAORF and mate behavior at sea.

3.3.5.2 Chaff Ships

Each of the scenarios contained one target ship on a course having a constant relative bearing fine on the port bow of ownship (i.e., less than 30°). In each case this ship would not obey the Rules of the Road and the ownship watch officer had to maneuver to avoid a collision. Since it was necessary that the subject not learn "the game" and just wait for the prime target ship to make an appearance, chaff ships were added to the scenarios with the purpose of masking the identity of the prime target ship. The chaff ships were also fine on the port bow and on collision courses, but these ships obeyed the rules and maneuvered at a range from ownship of 5 miles or more. The scenarios contained either one or two chaff targets and the chronological placement of the prime ship relative to the chaff ships, was varied between scenarios (A1 through B4), but fixed (e.g., A1V versus A1C) within any one scenario. By this technique it was hoped that the watch officer would be incapable of predicting which ship would not maneuver even after he had gone through several runs and had guessed that at least one would not change course.

Eleven answers were obtained to the question regarding recognition of chaff ship/target ship patterns and only one subject felt that he could discern which ship would fail to give way. The validity of this sole response was questionable since this subject had the highest frequency of initial maneuvers for chaff ships (4 out of 8). He indicated that he had an intuitive feel for the prime ship, but was obviously fooled 50 percent of the time.

Based on observation of subjects' performance and the subjective responses of 10 out of 11 subjects, it appeared that the chaff ships did accomplish their purpose and allowed for a subject's spontaneous reaction to the encounter since they did not/could not guess which threat ship would fail to alter course.

3.3.5.3 Environment

All eight watch segments took place under conditions of unlimited visibility and daylight conditions. Clear visibility was used so that there was no question concerning the applicability of the pertinent Rules of the Road; Rule 14 and Rule 17. Rule 14 concerned with head-on situations and Rule 17 for action by stand-on vessels are only in effect for vessels in sight of one another.

A question regarding the use of daylight conditions (as opposed to night) was posed during the subjects' debriefings to ascertain whether or not it would have been more or less difficult if runs had occurred during evening conditions. Fifty percent of the responses indicated that it would have been less difficult to make the runs under "night" conditions, due to the availability of target ship lights, while the other half of those questioned indicated that nighttime or day time conditions would have made no difference.

3.3.5.4 Bridge Equipment and Communications

Although the faculty for interbridge communication exists at CAORF in the form of VHF radio (connected to the Control Station), it was not made available to the watch officers during the running of this experiment. Along with the Collision Avoidance System (CAS), which is also on the CAORF bridge but was "down for repairs" during the experiment runs, it was felt that the inclusion of the availability of VHF (and CAS) would have simplified the encounter situations to the point of yielding inconsistent results; some subjects would have used it and others not. In addition, a reply from the give-way vessel would have indicated its intentions, thereby detracting from the accomplishment of the experiment

objectives. CAS is not universally available and is not always in an operating condition, and lack of a response to a VHF call during a potential collision encounter is also not a unique situation. Therefore, it was judged that these were realistic conditions.

The subjects were asked if they felt that the lack of VHF communication had caused a problem in their handling of the runs. Seven out of 15 responded that it was not a problem. Six out of 15 indicated that they would have preferred it and two said that it was no real problem but would have preferred it on segment A1 (approaching a fork in the fairway). The overwhelming response, though, was that it was not that abnormal to have received no response when using the radio. Therefore, the lack of bridge communications did not appear to affect their behavior in any detrimental manner.

3.3.5.5 Binocular Effects

All of the experiment runs placed ownship in a stand-on situation (or marginal head-on situation) once risk of collision had been determined. It was therefore essential for the watch officer to know whether the target ship on his port bow had made a maneuver, as was to be expected, or whether ownship would have to participate to avoid a collision. In a real life situation, the give-way vessel is normally tracked on radar and/or observed visually with binoculars to determine, as soon as possible, if the target ship had taken its "early and substantial action."

The visual scene at CAORF uses a TV type raster scan technique, and the resolution is a square of approximately 3/8 in. x 3/8 in. If a set of binoculars were to be used by a watch officer to look at a target ship at CAORF, the ship would look larger through the binoculars (i.e., subtend a larger angle at the eye) but would not be resolved any better. In other words, if the target ship consisted of say four units of resolution initially, it would still contain four units of resolution through the binoculars, although each unit would appear larger to the eye. Therefore, no additional information is obtained by viewing in this manner.

To overcome this difficulty, a closed circuit TV screen set up on the bridge was driven by a remote TV camera viewing a ship model, which was manually aligned to conform with the encounter situation. The model and camera were located at the Control Station. The watch officer would call the bow lookout to request a "binocular view" of a ship that he identified by range and relative bearing. The Control

Station operator (bow lookout) would measure the bearing of ownship relative to the target ship on his display and align the ship model accordingly. The view was then presented to the bridge for a short period of time on the TV monitor located on the bridge. The view was not constantly displayed because of the necessity of manually updating the model aspect and it was also felt that a continuous view would be distracting to the bridge watch officer.

Recognizing that this was an artificial technique which was used to overcome a mechanical limitation of the equipment, the subjects were questioned regarding the "binocular effects." A variety of responses were received but one third of the responses were positive (i.e., "good") and two thirds of the answers that were obtained either commented negatively on the placement on the bridge of the TV monitor or indicated a preference for a continuous, dynamically changing view. Although this technique did not meet with universal acceptance, it should be noted that all subjects did use the system for its designed, desired purpose. Most chaff ships were monitored in this manner by the mariners and the final decision to maneuver which was made by the ownship watch officer was usually made subsequent to a "last check to make sure."

3.3.5.6 Radar Usage

The new Rules of the Road have reinforced the usage of radar by means of Rule 5 and Rule 7. Rule 5 discusses a proper lookout by "all available means..." and Rule 7B refers to the use of radar equipment, radar plotting and equivalent systematic observation to obtain an early warning of risk of collision. The experiment runs were made under relatively ideal environmental conditions and radar was constantly being used by most of the watch officers. The subjects were asked if they felt that they had used the radar more than on their own ships and 9 out of 14 indicated they had used it a normal amount (or same as on their own ship), but 5 out of 14 said they used it more at CAORF. The reasons given for increased radar use fell into two areas. The fact that the radar was available, working, adjusted and turned on, was cited as one of the causes and the other was a generalized concept of need. Since eight scenarios were run within two days of "real time" and each scenario contained a risk of collision situation, the overall impact of a constant need for the equipment existed since all of the situations required it. Several masters had also indicated a maintenance factor as a reason for not making extensive use of radar equipment aboard their own ships. They would prefer to "save the usable operating hours until they were really

needed - poor visibility close to shore." It is interesting to note that no one really related their use or extent of use of radar to the change in the Rules of the Road although Rule 5 now requires a proper lookout.

3.3.5.7 Rules of the Road

References can be found in the literature, and were discussed in the background portion of the first section of this report, concerning the actual behavior pattern of mariners in a stand-on situation, in contrast to the requirements of the Rules of the Road; the so-called burden of being privileged. As previously indicated a maneuver tended to be made "early", before the rules came into effect, or was made as sanctioned by the good seamanship concepts. The new rule (17) allows a maneuver prior to the extremis position and a question was posed to all subjects, after their experiment runs, as to whether or not they felt that they would have handled the encounter situations differently prior to July 1977; i.e., did the new rules change their reactions in these stand-on encounters. Two out of 18 watch officers indicated that they felt that they were performing in a different manner - these mariners were both VLCC chief mates. One containership master was hesitant but finally admitted that there was no difference and the remaining 15 indicated that their performances were the same under both sets of rules. All mariners indicated satisfaction that this behavior pattern of maneuvering prior to the extremis position is now more clearly acceptable under the new rules.

3.3.5.8 Nationality

The 18 subjects that were used in this investigation consisted of 13 U.S. nationals and 5 foreign nationals. This breakdown was not anticipated nor planned at the outset of the experiment but was caused by the need for experienced VLCC watch officers. Once it became apparent that this additional "quasi-variable" was present, it was balanced across the experiment with two foreign nationals placed in the untrained subject group and three placed in the trained group. Therefore, from an experimental viewpoint, the effects were minimized. It should be reemphasized that the experiment was not designed to compare differences in behavior as a function of nationality.

An interesting tendency emerged from the investigatory findings. That is, foreign VLCC watch officers (both trained and untrained) appeared to maneuver at a larger average range and achieve a larger average CPA than their U.S. counterparts. However, caution must be exercised in

using this apparent trend as a "reliable, hard fact" because of the limited number of data points upon which it is based. It does suggest a subject for conducting additional studies to determine whether or not nationality is correlated with significant differences in ship handling behavior.

3.3.6 VLCC Privileges

Rule 18 of the revised Rules of thé Road has placed the deep-draft vessel in a "pecking order" which yields it privileges over fishing vessels and sailing vessels and makes it subservient only to "not under command" vessels or vessels restricted in their ability to maneuver. This placement is dependent upon the restriction because of draft, and therefore vessels such as VLCCs obtain these rights only when showing the appropriate signal, which in turn is due to the available depth of water (Rule 28). The VLCCs though are large, ponderous vessels with turning and stopping characteristics which place them at a relative disadvantage compared to more highly maneuverable vessels. But even the new rules do not take these characteristics into account. What therefore is the reaction of watch officers to privileges outside of the constraint of the rules, and could this be the cause of non-give-way or late stand-on maneuvering action on the part of VLCC mariners? This question was posed to all of the subjects (both VLCC and containership) during the final debriefings at the end of their experiment runs.

Three VLCC watch officers (none from containerships) felt that a VLCC should be given a wider berth, would steam through fishing fleets, etc., even when not in shallow waters. A comparison of the attained results of these three three watch officers and the results from their overall class, i.e., trained or untrained grouping of six subjects, is shown below.

Subject	Group	Group Mean (nm)		Subject Mean (nm)	
		Range	CPA	Range	CPA
#72	Untrained	3.86	0.42	3.80	0.53
#71	Untrained	3.86	0.42	2.57	0.18
#68	Trained	4.16	0.54	3.91	0.41

It is interesting to note that subjects No. 72 and 68 performed at a level which was fairly consistent with their group averages, which is certainly an indication that, even though they expressed an opinion regarding VLCC privileges, their performances did not reflect this attitude.

The range and CPA of subject No. 71 though appears to be well below the averages of his group. He was also the master that was involved in one of the two collisions and one of the three near misses discussed in paragraph 3.4.2. It certainly appears that his performance does reflect his comments made during his overall final debriefing.

3.4 CONCLUSIONS AND RECOMMENDATIONS

This investigation clearly revealed significant differences in watch officer behavior aboard a stand-on vessel in risk of collision situations under the new International Rules of the Road, for the following:

- Training in the revised Rules of the Road vs No-Training
- VLCC vs containership watch officers
- Vessel encounter situations with maneuvering restrictions on the right vs no restrictions
- Clear-cut crossing vs ambiguous crossing situations
- Low traffic density vs high traffic density

It also showed that the new Rule 17(a)(ii) for allowable stand-on vessel actions did not result in excessively large maneuvering ranges. Therefore, watch officer behavior remains predictable in these collision avoidance situations and the give-way/stand-on vessel concept of the steering rules has been maintained.

3.4.1 Training Effects

- The training program was found to be effective in increasing the mariners' knowledge of the changed Rules of the Road as measured by testing prior to the training and after the experiment runs. A significant improvement was found in post-experiment test scores compared to pre-experiment test scores of the trained groups and, in addition, higher post-experiment test scores were obtained by the trained VLCC group, compared to the untrained group.

- A transfer of training to the simulator was shown. The trained mariners exhibited a consistency in their maneuvering range which is attributed to the training that they had received. This consistency in their maneuvering was measured by the mean of the standard deviations of the range at maneuver.

- The number of course changes per maneuver for the trained VLCC group was found to be smaller than for the untrained group and therefore, may also be attributed to training. The desirability of large recognizable course changes is fundamental to good seamanship and was underscored in the training program. A single maneuver is more recognizable than a series of small course changes which add up to the same overall maneuver magnitude. Therefore, the fact that the trained group accomplished their larger course changes with a significantly smaller number of changes per maneuver shows that they were more decisive than the untrained group and that there was a transfer of training to bridge behavior in this area, also.

- Rule 14 allows an ambiguous crossing situation to be judged as a meeting situation and this fact was emphasized in the training. The trained group took advantage of this rule change. This was indicated by the larger CPA attained by this group, compared with the untrained group, for this type of crossing encounter. It was also shown that the trained group obtained significantly larger CPAs (for ambiguous encounters) when there were restrictions to starboard.

- This experiment suggests that any effective training program which increases the mariners knowledge of the new Rules of the Road, would most probably result in more desirable behavior patterns. Example of such improved behavior are the consistency of maneuvering range and small number of course changes per maneuver both of which were found to be related to overall knowledge of the changed rules.

3.4.2 Ship Type Effects

- The mean range at which the stand-on vessel watch officers made their escape maneuvers was found to be about 4 nm and independent of the type of ship or their training status regarding the changes to the Rules of the Road. The attained CPAs though were substantially different, i.e., larger for the containership masters compared with the VLCC officers. Since the size of the

maneuvers was also significantly different (larger for the VLCC watch officers), analyses were performed "offline" to determine the CPAs that could be realized by both types of vessels. The analyses were based on efficient maneuvering at various maneuver magnitudes when the actions were initiated at the mean range for all runs (4 nm). The results of these analyses indicate that containership mariners could have achieved practically any CPA that they desired (1 to 3 nm) dependent on the size of the maneuver employed and the efficiency of the course change (number of changes per maneuver). The potential CPA available to these containership mariners at a 4 nm maneuvering range was large because of the turning and speed characteristics of their vessels and they, therefore, had a large "reserve CPA," i.e., a large difference between potential and achieved CPA. Alternatively, the analyses also indicate that the VLCC mariners could not have obtained much larger CPAs than they did on the simulator when the maneuver was initiated at 4 nm. The analyses demonstrated that the best possible CPAs for the VLCC masters at this range were as low as 0.50 nm and as high as 0.95 nm, the latter resulting only from extensive 70^{o} or 90^{o} maneuvers. Based on the turning and speed characteristics of these vessels, the VLCC watch officers' behavior reflects the small reserve CPA that was available to them. The VLCC mariners attempted to abide by the changed rules by not maneuvering at extreme ranges (greater than 5 nm), but the inherently limited maneuverability of their vessels constrained their attained CPA. Most mariners anticipate a give-way vessel taking action at a range of 5 or 6 nm and, therefore, maintain their course and speed at least to that point in an encounter when they are conning the stand-on vessel. This appears to present a paradox for the VLCC mariners. The VLCC officers could have attained the same "reserve CPA" as the more maneuverable vessels,but only by means of extensive maneuvering at ranges which are beyond the guideline (2 - 4.5 nm) indicated by commentary found in related maritime literature on the changed Rules of the Road.

- The paradox resulting from the reserve CPA concept noted above apparently caused far smaller attained CPAs than the VLCC mariners themselves had indicated that they desired.

- The VLCC mariners were more concerned with the encounters containing restrictions on the right, which was indicated by the fact that they performed significantly more non-standard maneuvers than the containership watch officers did. The VLCC officers also maneuvered at significantly larger ranges during these restrictive encounters compared with their maneuvering when no restrictions were present.

- The type of restriction had a differential effect for the VLCC watch officers. They performed a larger number of non-right maneuvers for oil rigs adjacent to safety fairways than with shoal water. The fairways themselves also exerted a constricting effect.

- The VLCC officers took advantage of the ambiguous crossing rule (14c) and maneuvered at larger ranges under ambiguous crossing conditions than in clear-cut crossings. This occurred under low and high traffic density conditions for VLCC officers, while it occurred only under high traffic conditions for the containership watch standers.

3.4.3 Conclusions

The sound-slide/case-study training program regarding the new Rules of the Road was shown to be effective. Not only did it increase the masters' knowledge and understanding of the new rules, but it also resulted in improved performance on the bridge simulator. These findings demonstrate that a decision-making training program regarding the new rules can achieve improved performance by the master.

It has also been shown that in situations covered by the International Rules of the Road, the changes regarding stand-on vessel responsibilities were not disruptive, as had been feared. The modified rule for stand-on vessel actions, Rule 17(a)(ii), did not result in excessively large maneuvering ranges. Therefore, the predictability of actions under these conditions had been maintained along with the orderliness and safety inherent in the give-way/stand-on vessel concept.

The fine crossing situations between a high speed containership and a slower VLCC, when the latter is the stand-on vessel, is inherently difficult. The new Rules of the Road do not adequately address the situation with regard to the action of the stand-on vessel. When the VLCC watch officer does react properly, in accordance with the rules and his previous experience, he has placed himself in a situation in

which the inherent maneuvering limitations of his vessel restricts his passing distance to a non-maneuvering give-way vessel. The attained CPA is then at a level which is considerably less than he desires.

3.4.4 Recommendations

As a consequence of the analyses and observations made during the study, several areas for further investigations became apparent and are presented below:

1. Conduct a follow-up experimental investigation using CAORF to determine the long-term effects of training.

2. Evaluate the transfer of training between the CAORF simulator and the at-sea operational setting.

3. At some subsequent date, utilize CAORF to retest the untrained VLCC officers who were employed in this experiment to determine what effect interim at-sea experiences have had on their performance.

4. Expand the present experiment by testing six additional containership watch officers, as an untrained group, under the same experiment conditions. This would allow a comparison of the effect of training on containership mariners per se, as well as provide a larger data base for comparing performance as a function of ship type.

5. Using the CAORF simulator, expand the present experiment to include (a) a broader spectrum of ship types, crossing angles and relative closing velocities, (b) encounter situations in which both the give-way and stand-on vessels are either VLCCs or containerships, (c) night conditions with vessels in sight of one another, (d) a broader population of watch standers such as second and third mates, and (3) additional response variables to measure the effect of watch officer workload.

6. Investigate the relationship of the mariners' stress levels (e.g., as measured by heart rate) and/or their tendency toward risk-taking (e.g., as measured by paper and pencil test scales and inventories) with performance under varying scenario conditions (e.g., maneuvering restrictions).

7. Investigate further the possible differences in behavior between U.S. and foreign masters through more comprehensive and in-depth experimentation and expansion of the subject sample.

8. Investigate the ramifications of the types of maneuver restrictions causing differential concern (oil rigs vs. shoal water) as well as constraints imposed by quasi-legal restrictions such as fairways.

9. Conduct a follow-up experimental investigation comparable to this study, using test subject groups based solely on knowledge of the Rules of the Road. All subjects could be given the same test prior to experiment runs and ranking of test scores could serve as the basis for assigning subjects to groups for analytical comparison purposes. The experiment could be performed in concert with #4 above.

CHAPTER 4
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APPENDIX A

SCENARIO DIAGRAMS & CONTACT LISTS

Scenario Diagrams

Visual Contact List

Radar Contact List

Watch Contact Lists

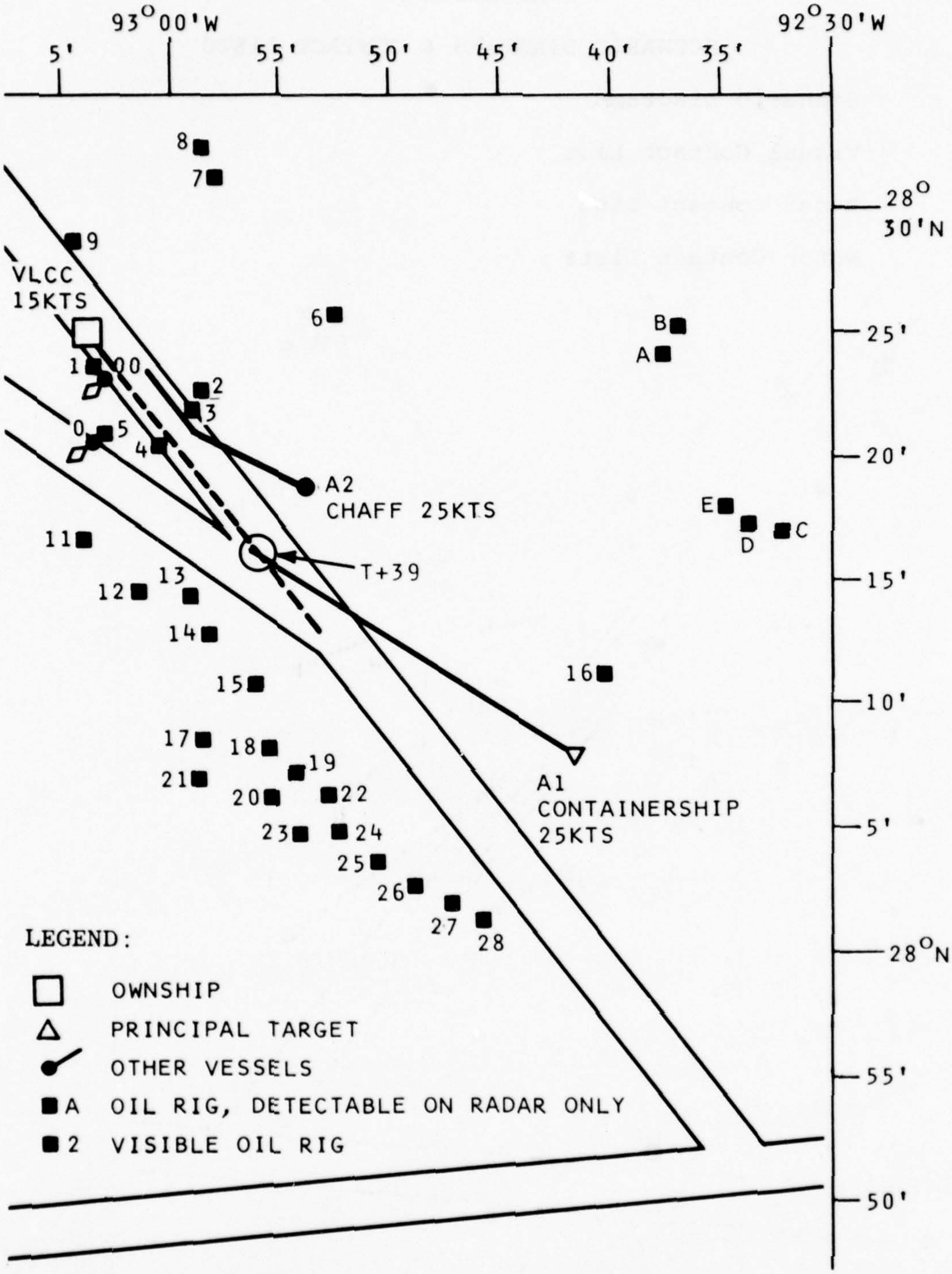


Figure A-1. Gulf Port Watch Segment: A1V (Watch A, First Segment, VLCC).

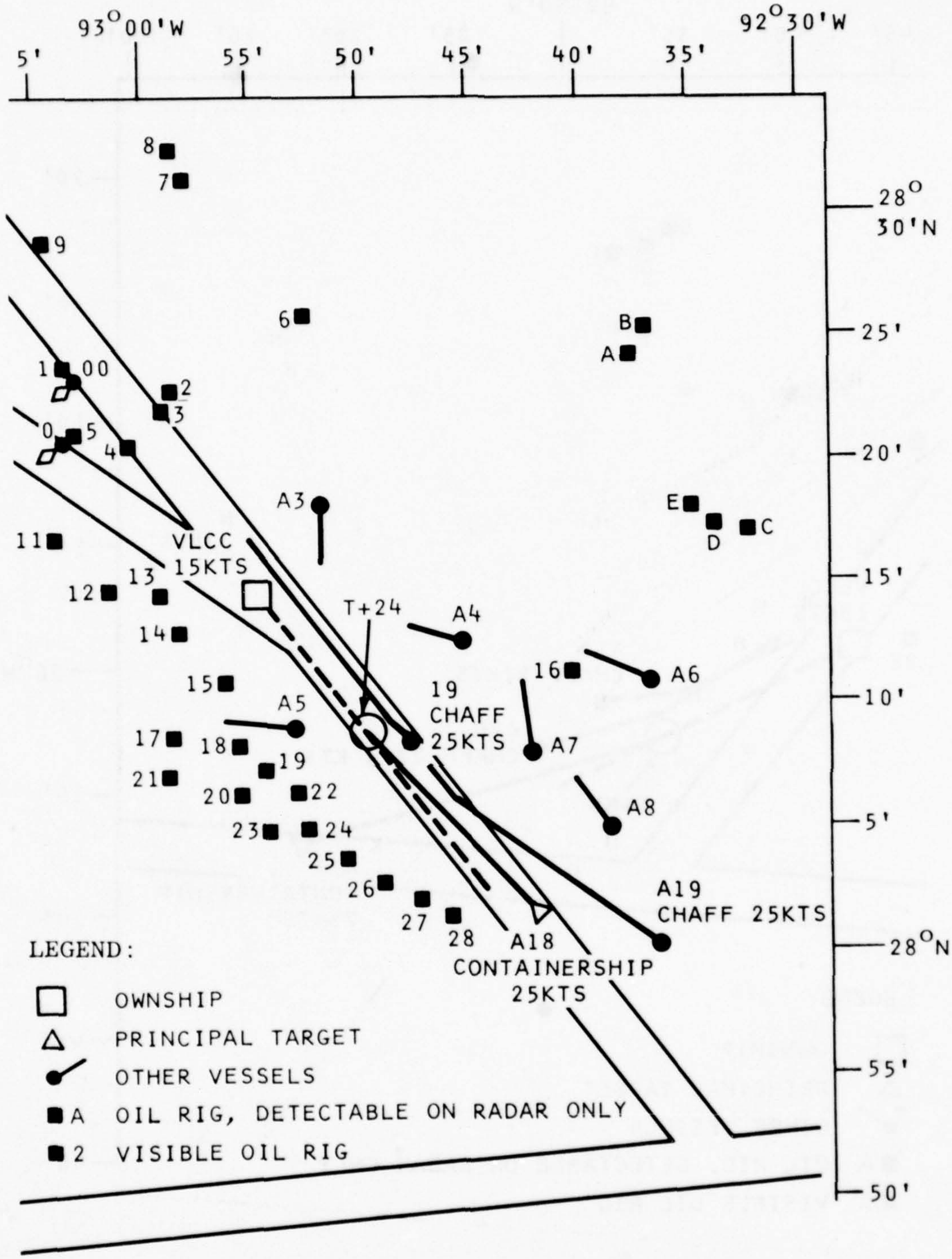


Figure A-2. Gulf Port Watch Segment: A2V (Watch A, Second Segment, VLCC).

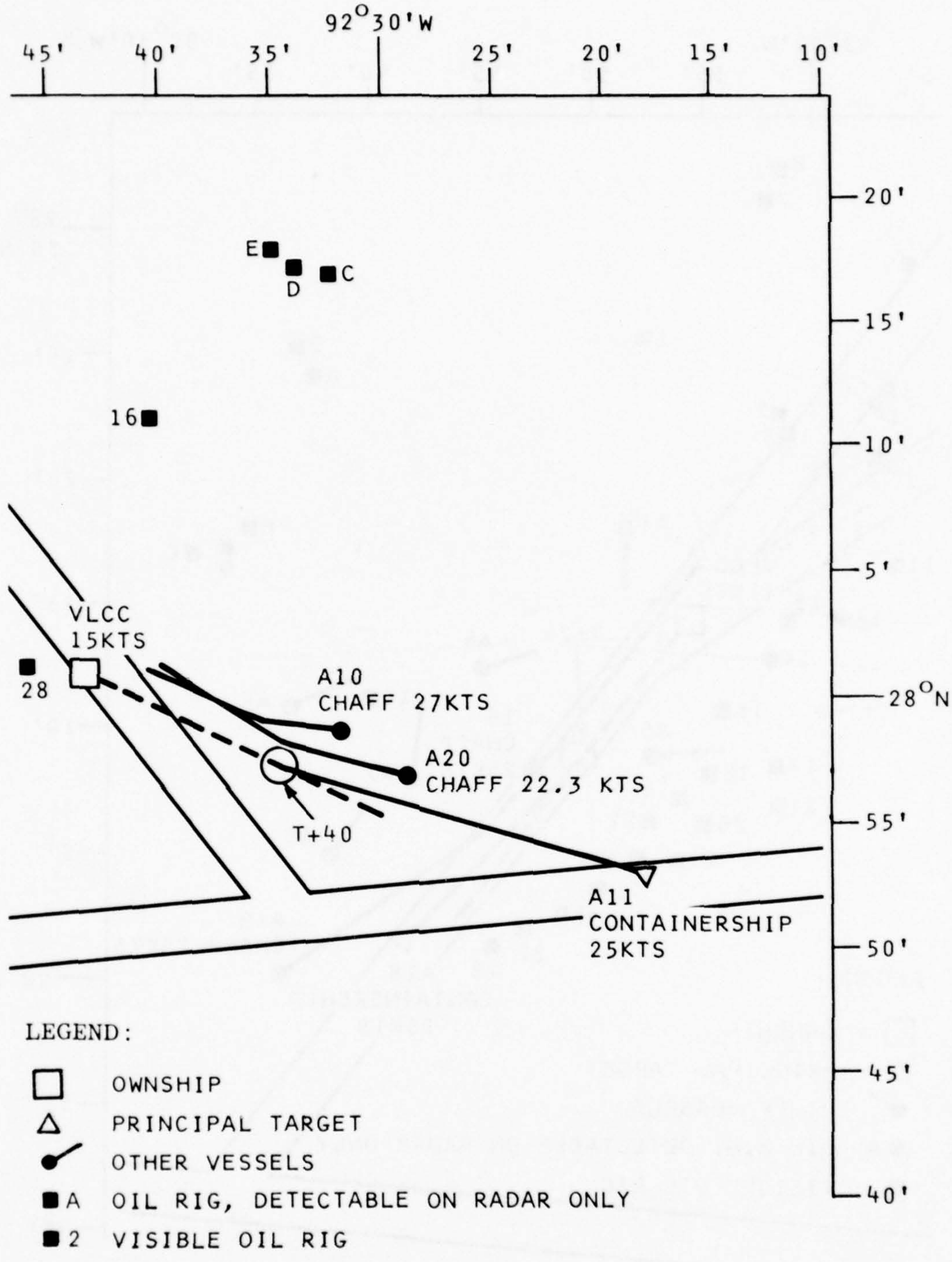


Figure A-3. Gulf Port Watch Segment: A3V (Watch A, Third Segment, VLCC).

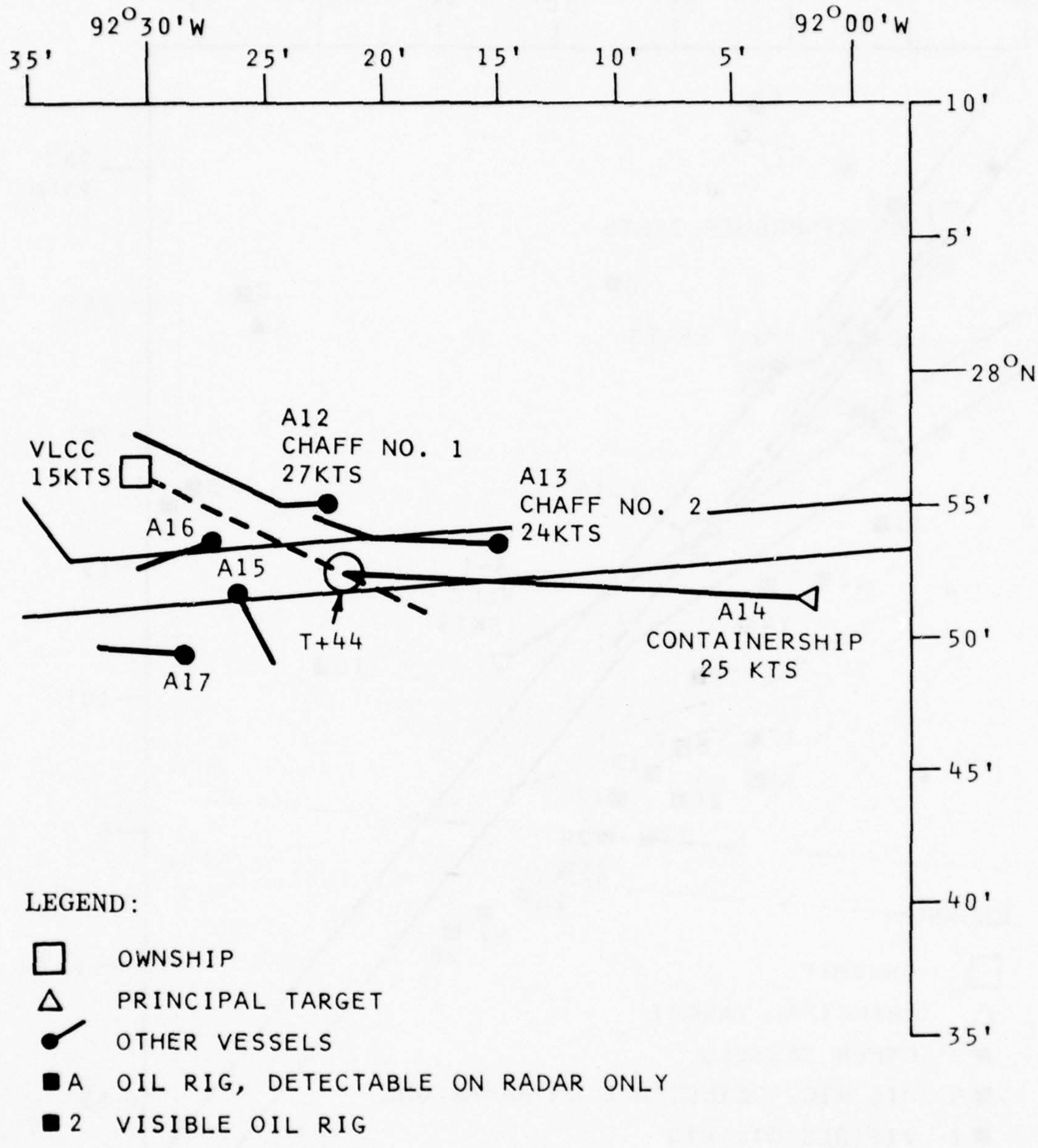


Figure A-4. Gulf Port Watch Segment: A4V (Watch A, Fourth Segment, VLCC).

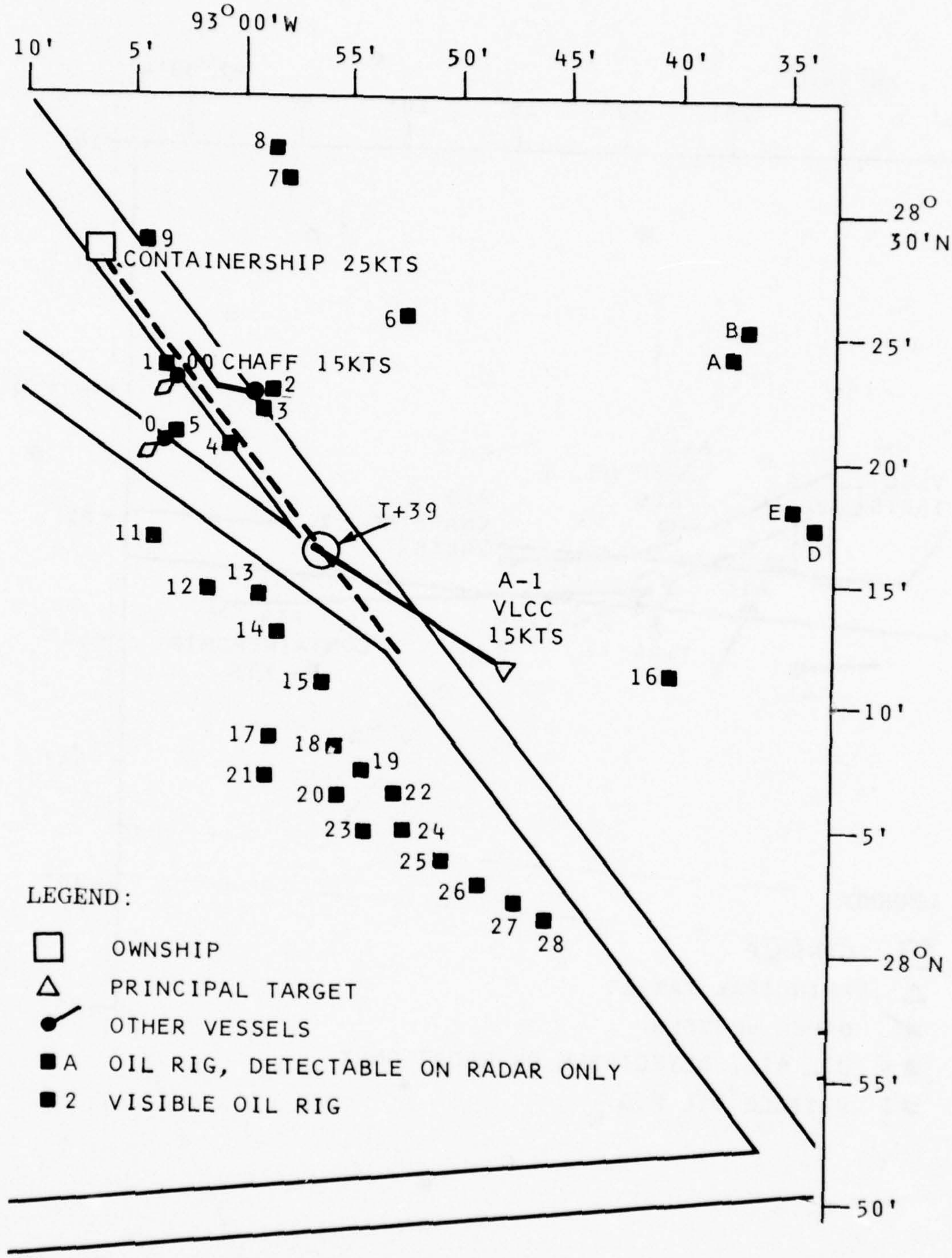


Figure A-5. Gulf Port Watch Segment: A1C (Watch A, First Segment, Containership).

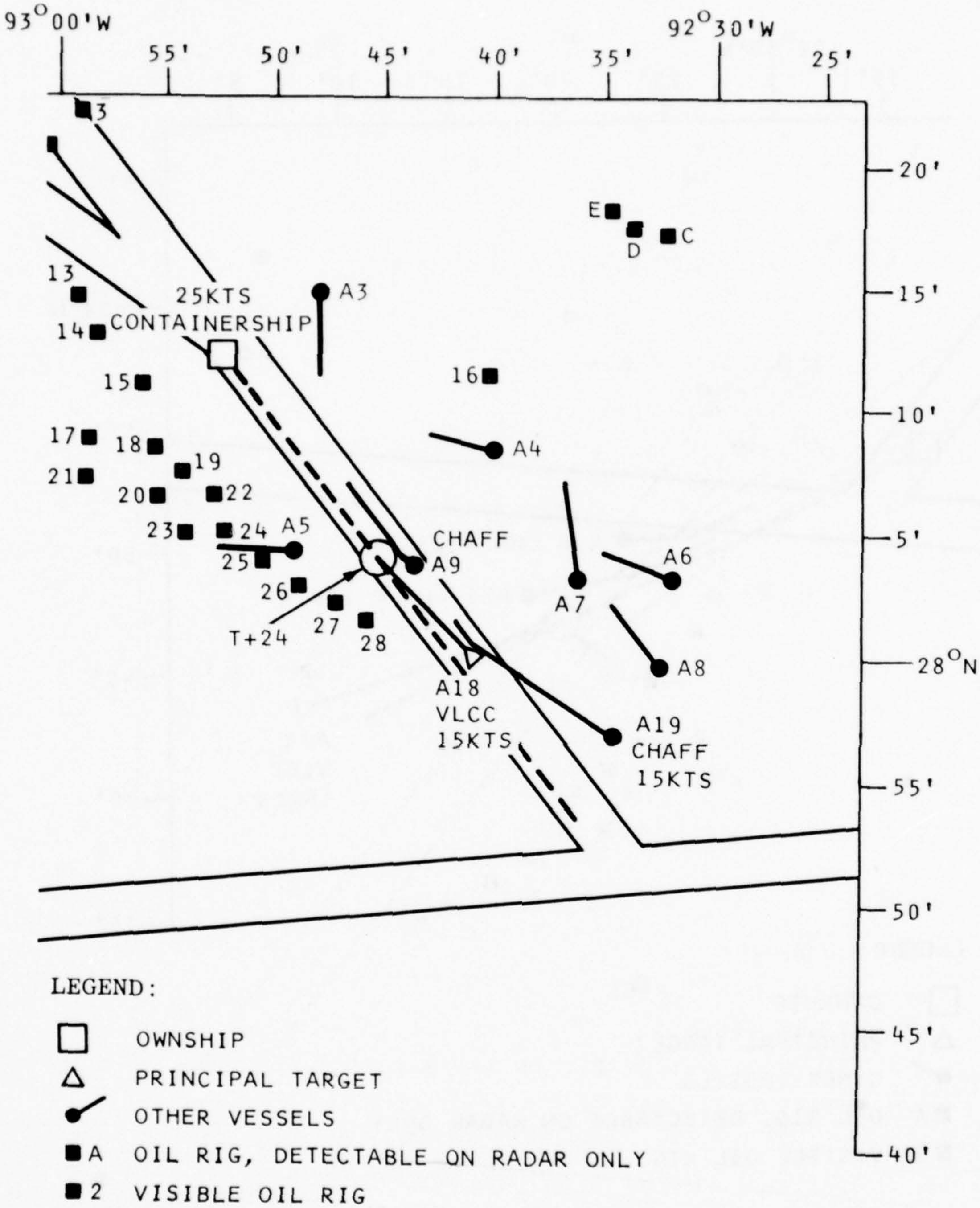


Figure A-6. Gulf Port Watch Segment: A2C (Watch A, Second Segment, Containership).

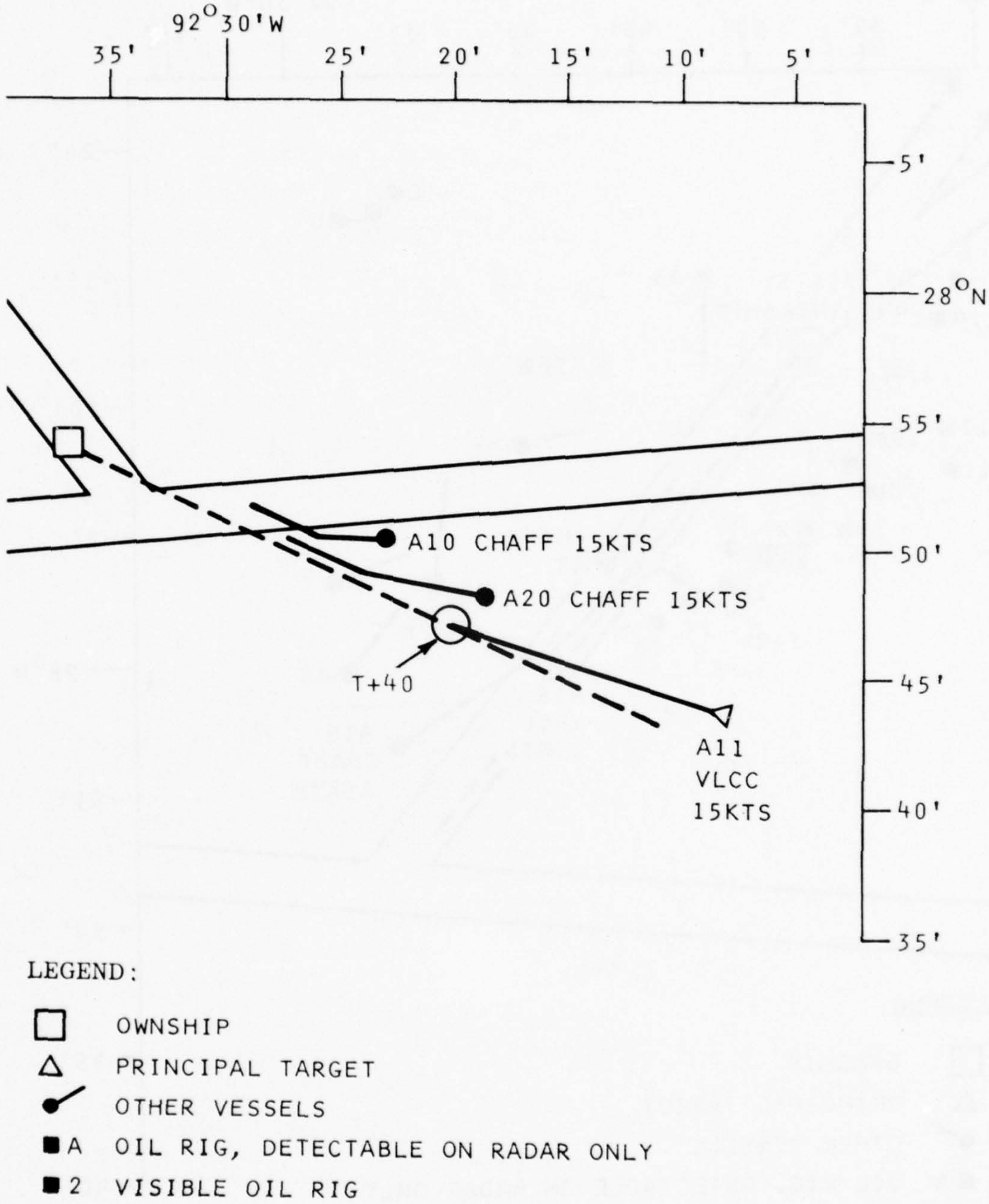
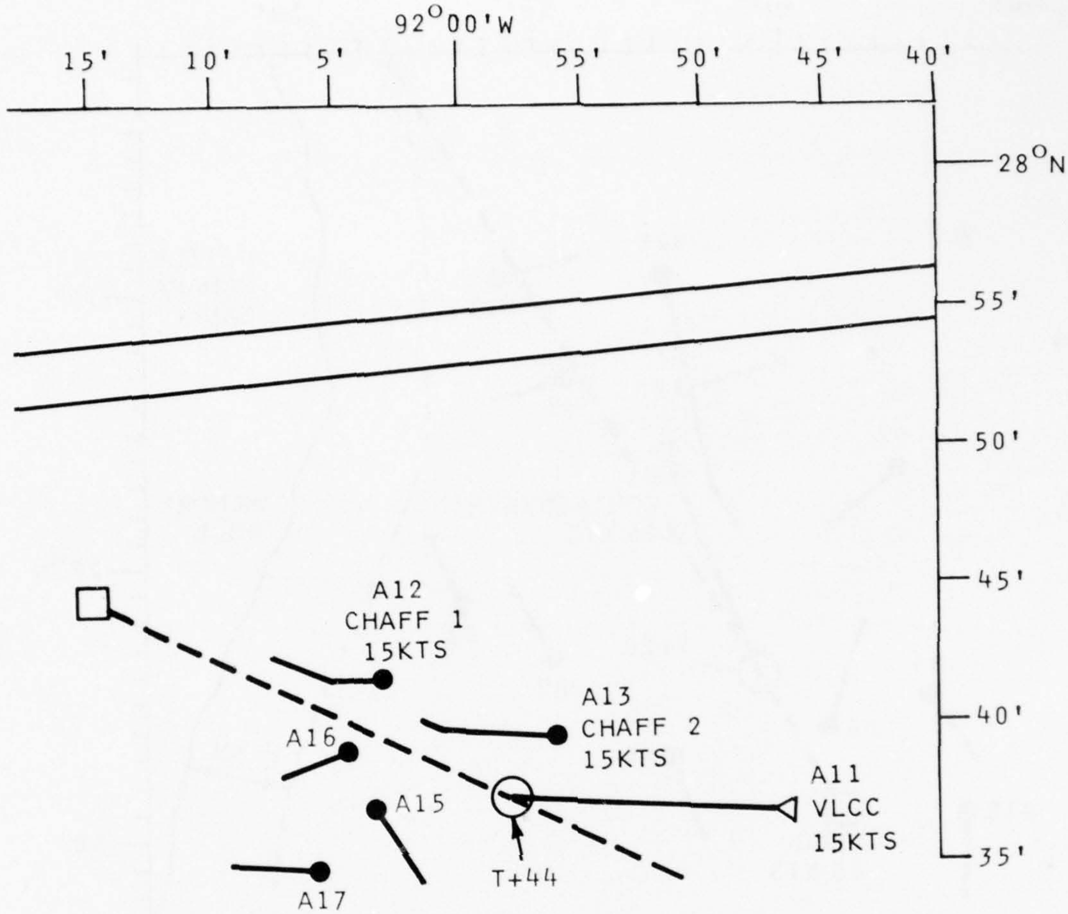


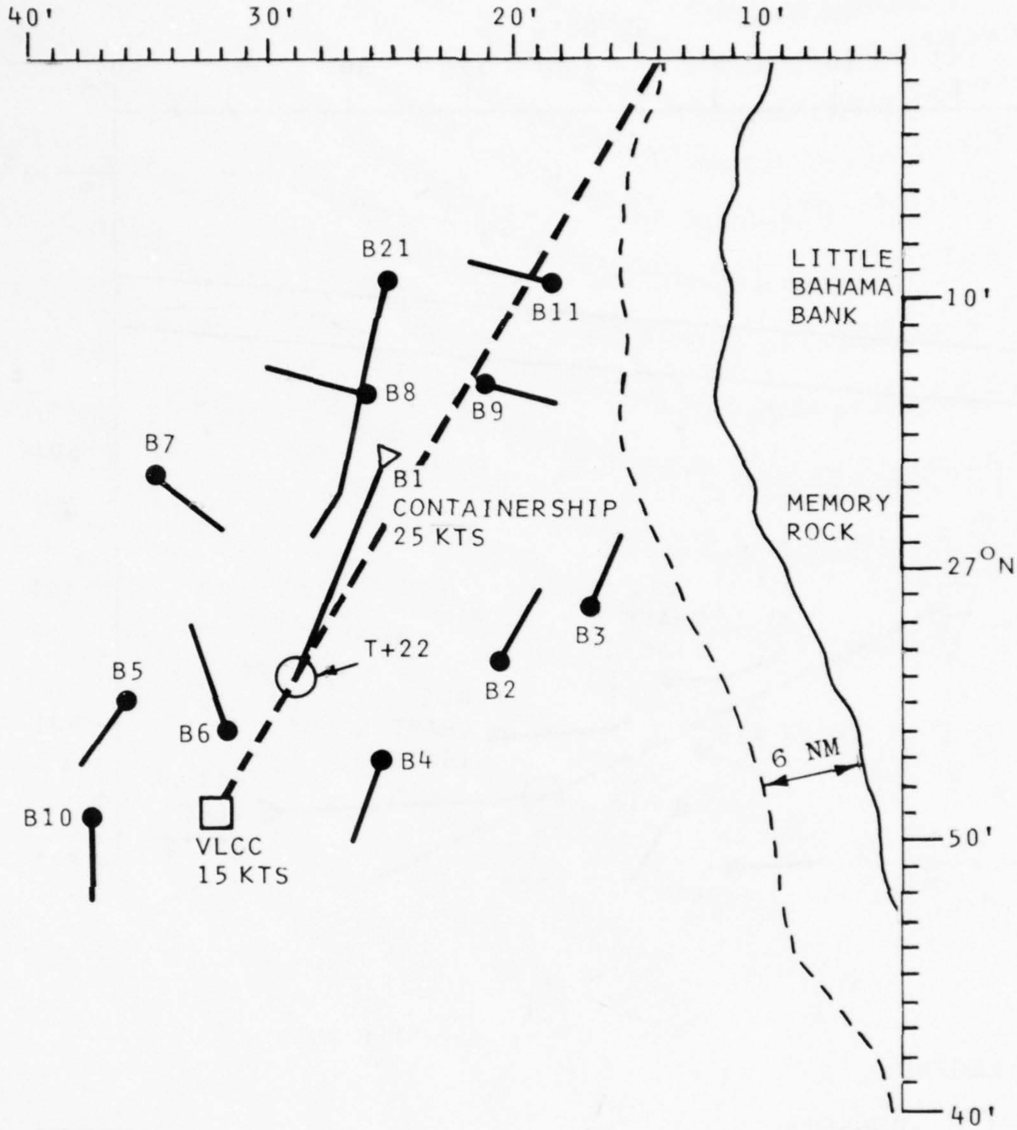
Figure A-7. Gulf Port Watch Segment: A3C (Watch A, Third Segment, Containership).



LEGEND:

□ OWNSHIP
△ PRINCIPAL TARGET
OTHER VESSELS
■ A OIL RIG, DETECTABLE ON RADAR ONLY
■ 2 VISIBLE OIL RIG

Figure A-8. Gulf Port Watch Segment: A4C (Watch A, Fourth Segment, Containership).



LEGEND:

- □ OWNSHIP
- △ PRINCIPAL TARGET
- ● OTHER VESSELS

Figure A-9. Matanilla Shoals Watch Segment: B1V (Watch B, First Segment, VLCC).

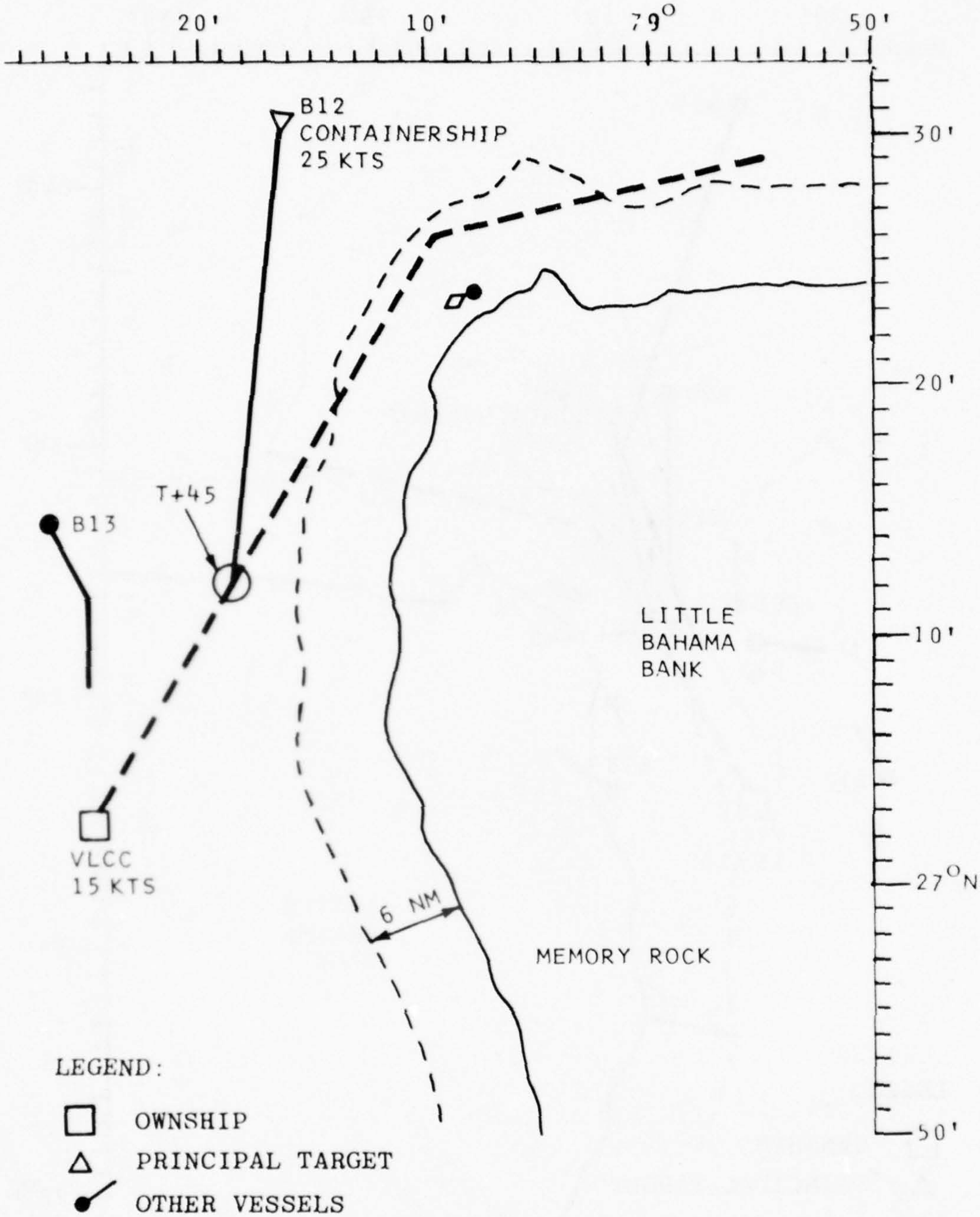


Figure A-10. Matanilla Shoals Watch Segment: B2V (Watch B, Second Segment, VLCC).

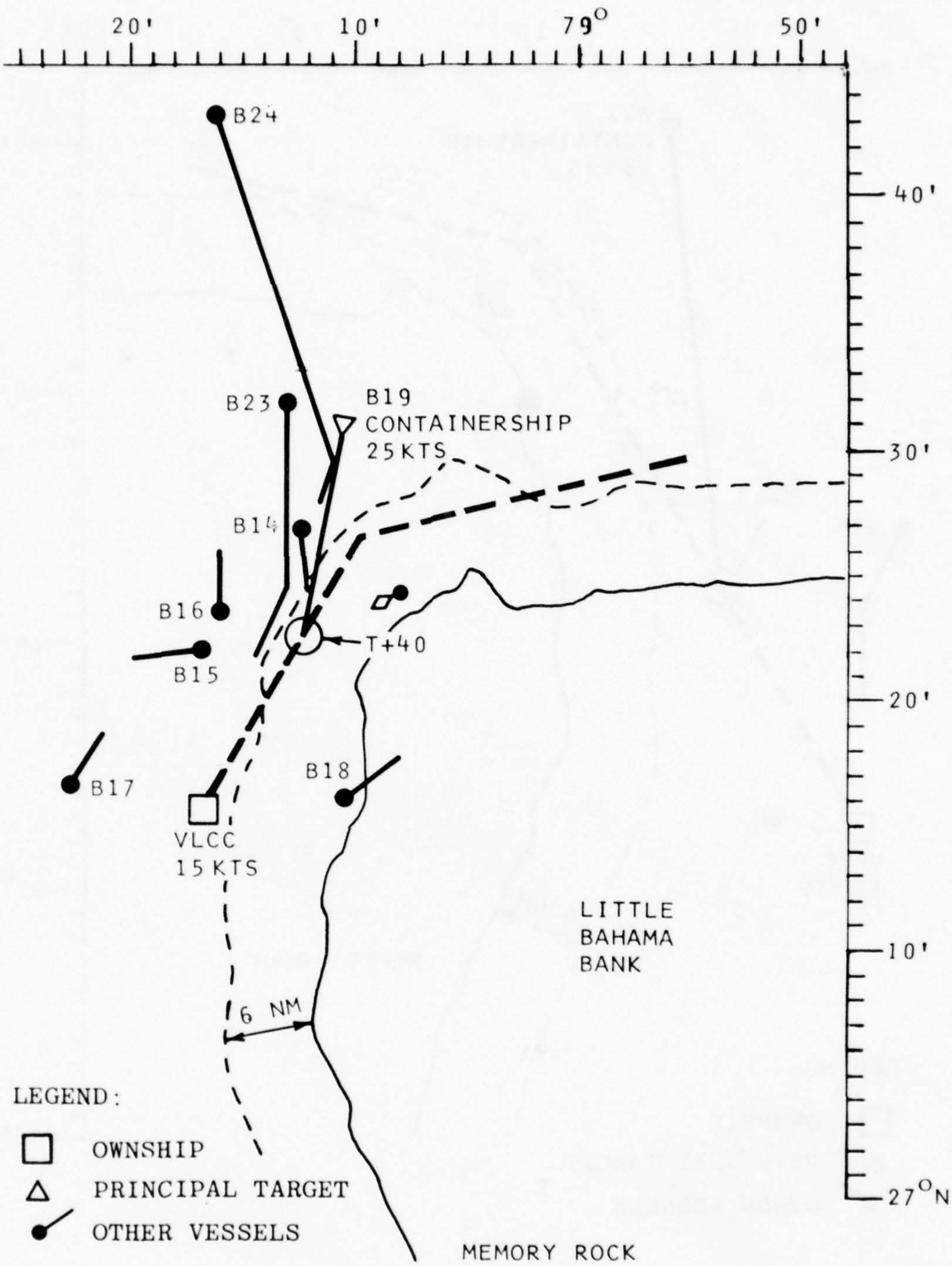


Figure A-11. Matanilla Shoals Watch Segment: B3V (Watch B, Third Segment, VLCC).

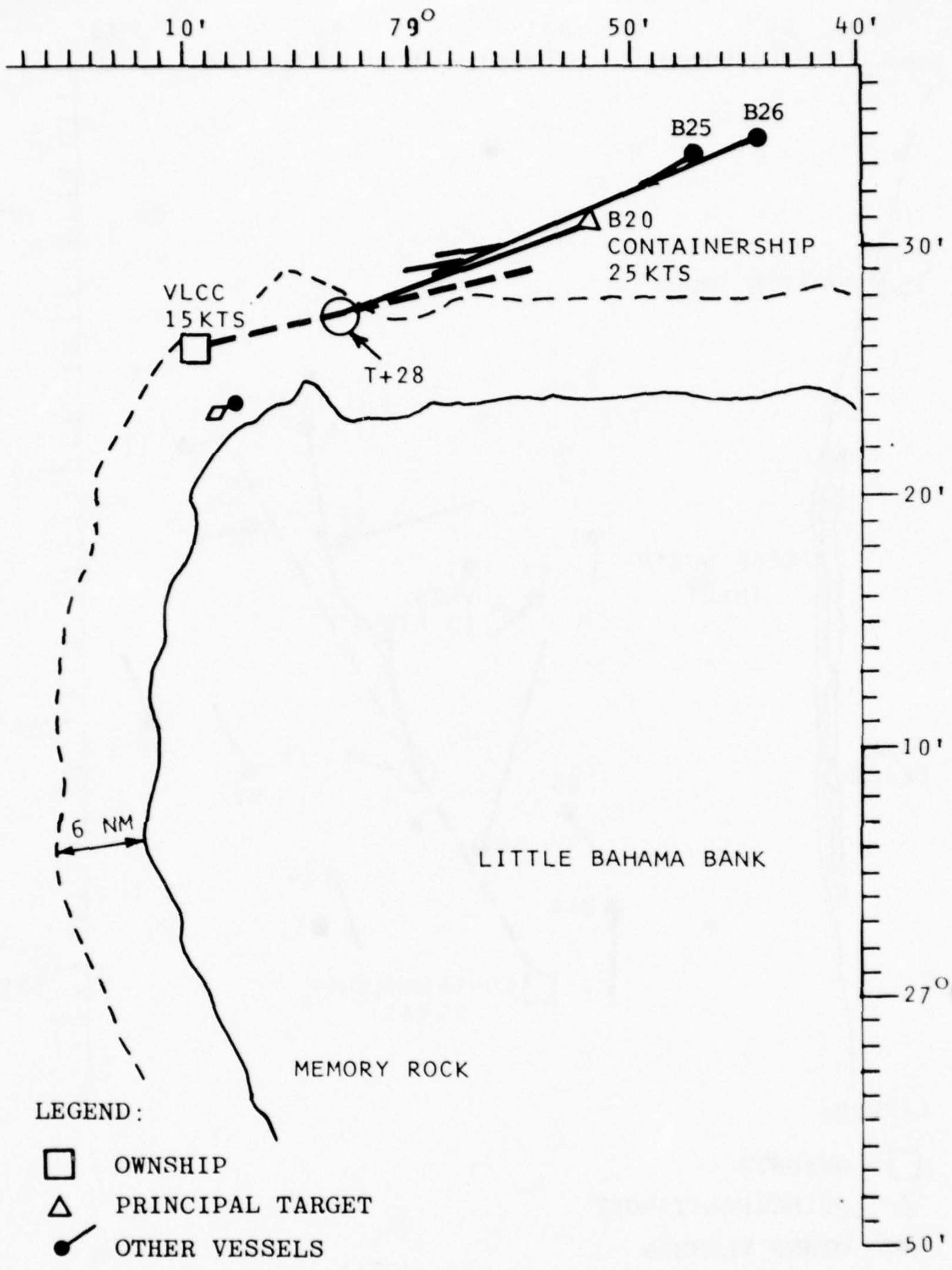


Figure A-12. Matanilla Shoals Watch Segment: B4V (Watch B, Fourth Segment, VLCC).

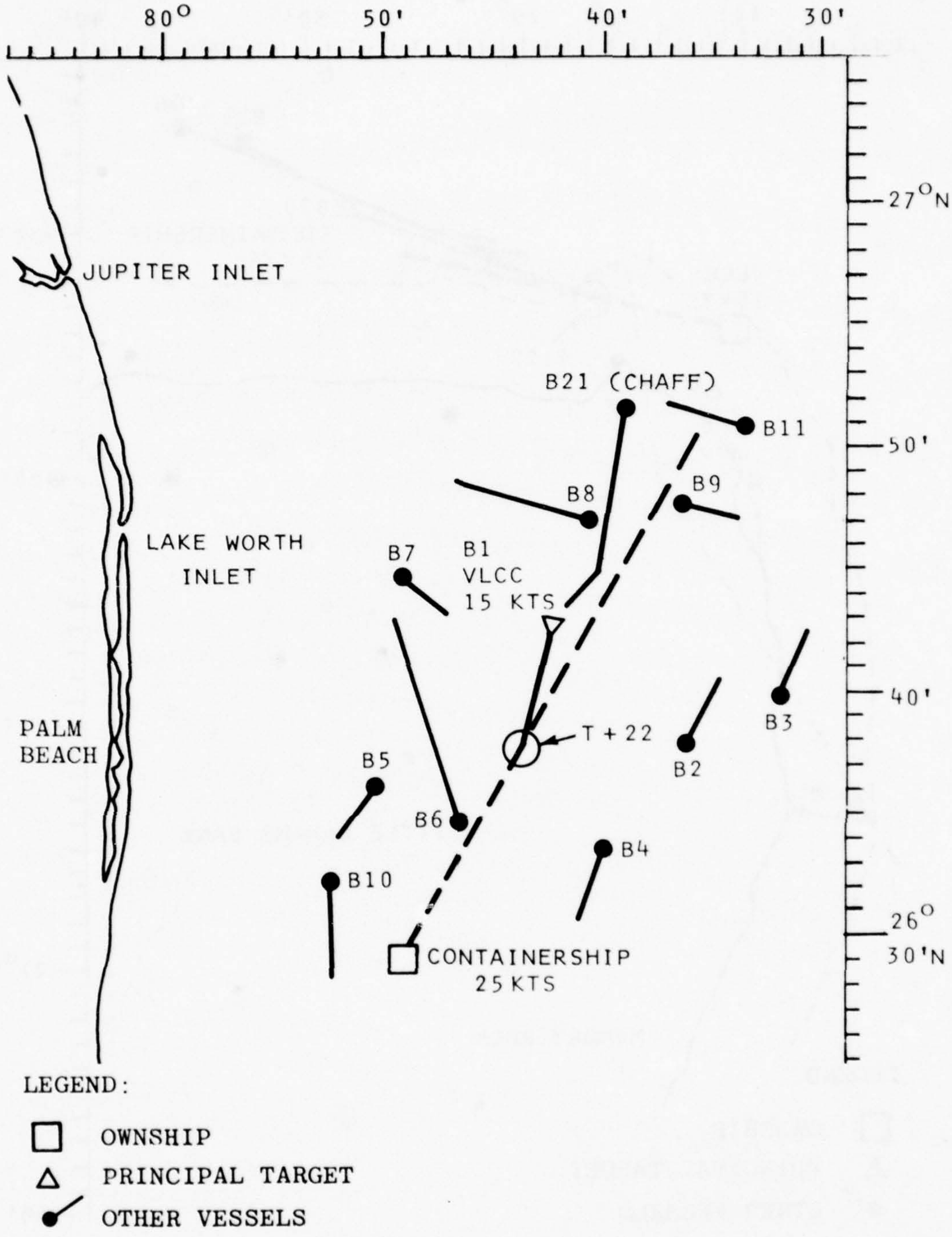


Figure A-13. Matanilla Shoals Watch Segment: B1C (Watch B, First Segment, Containership).

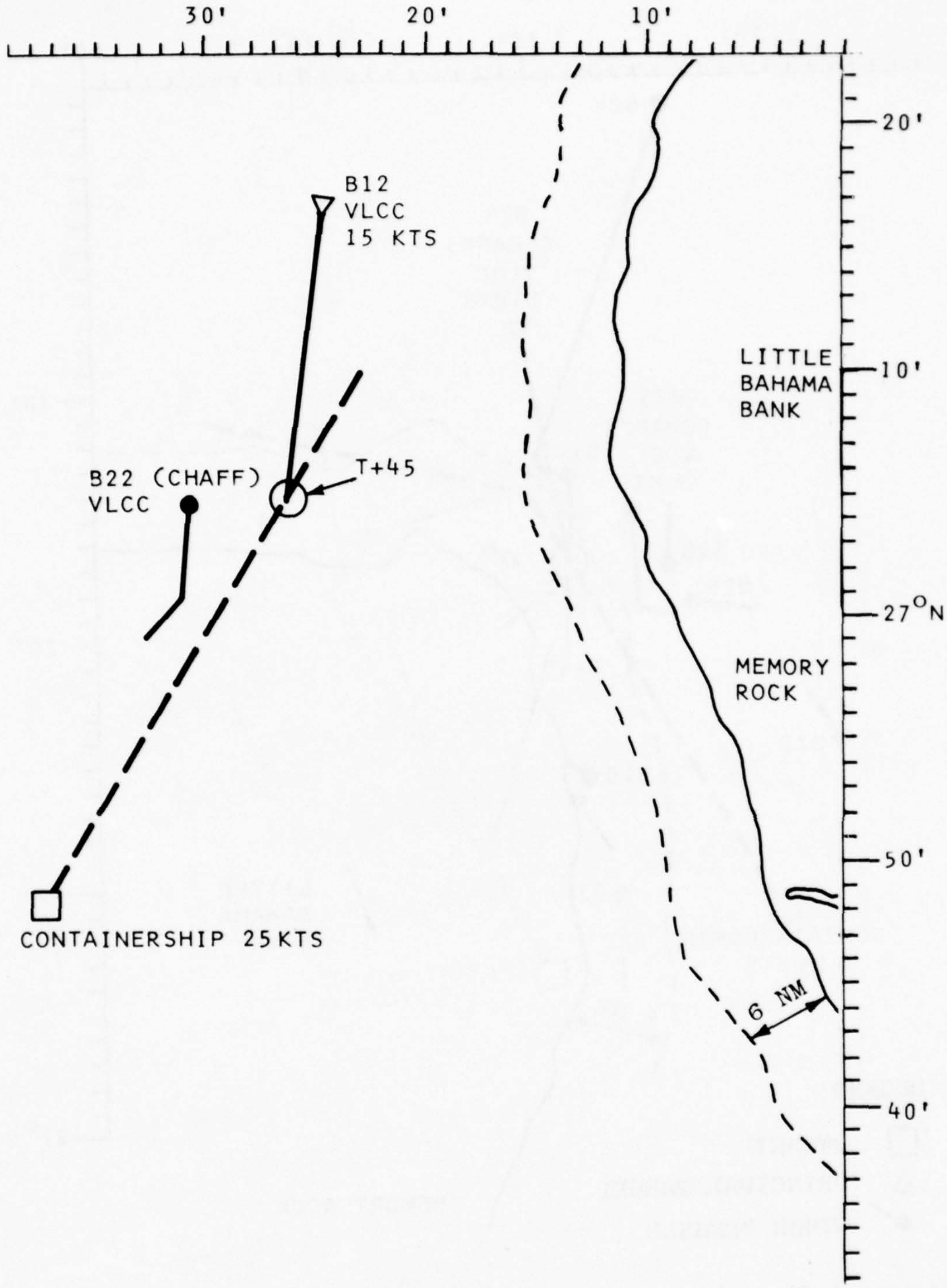


Figure A-14. Matanilla Shoals Watch Segment: B2C (Watch B, Second Segment, Containership).

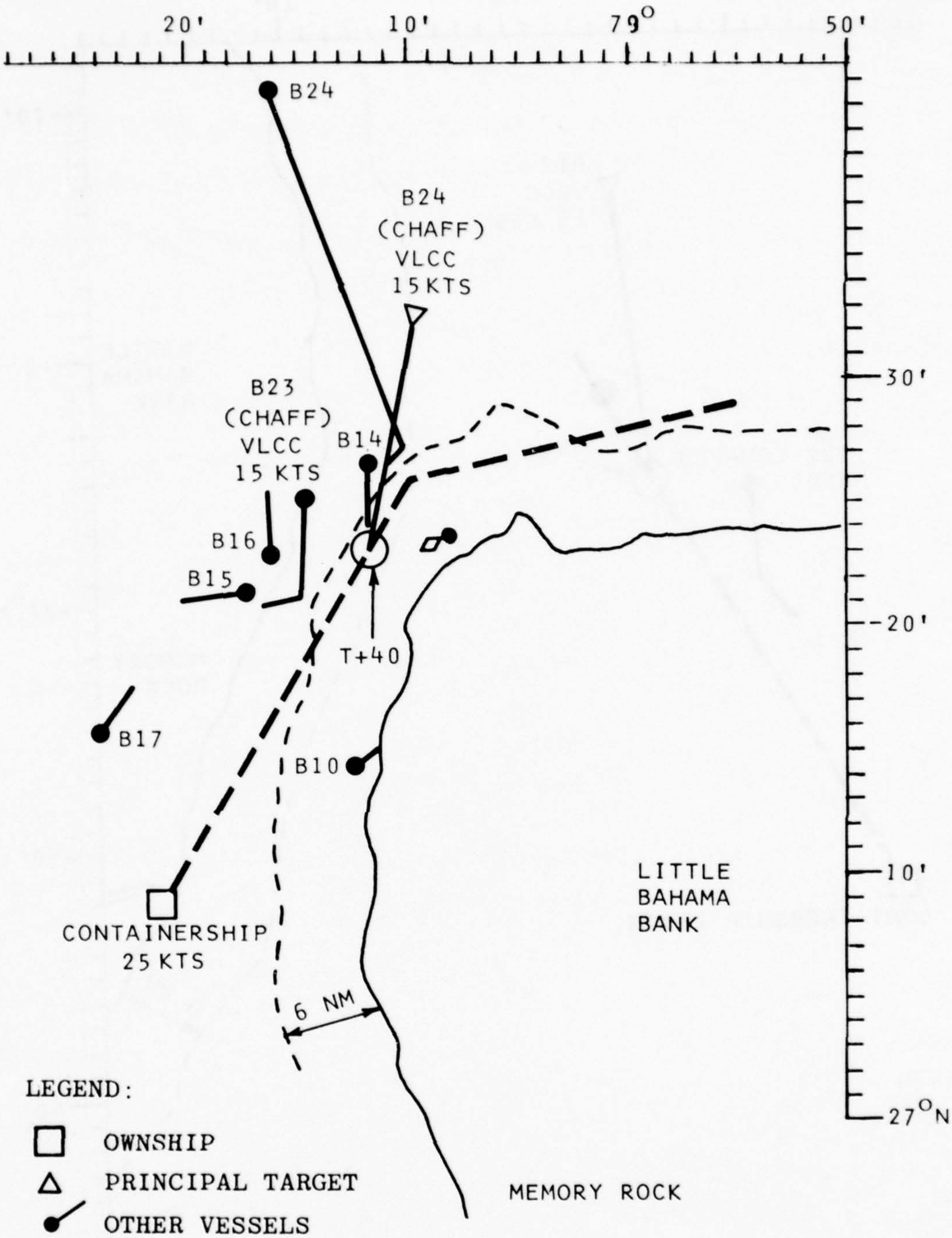


Figure A-15. Matanilla Shoals Watch Segment: B3C (Watch B, Third Segment, Containership).

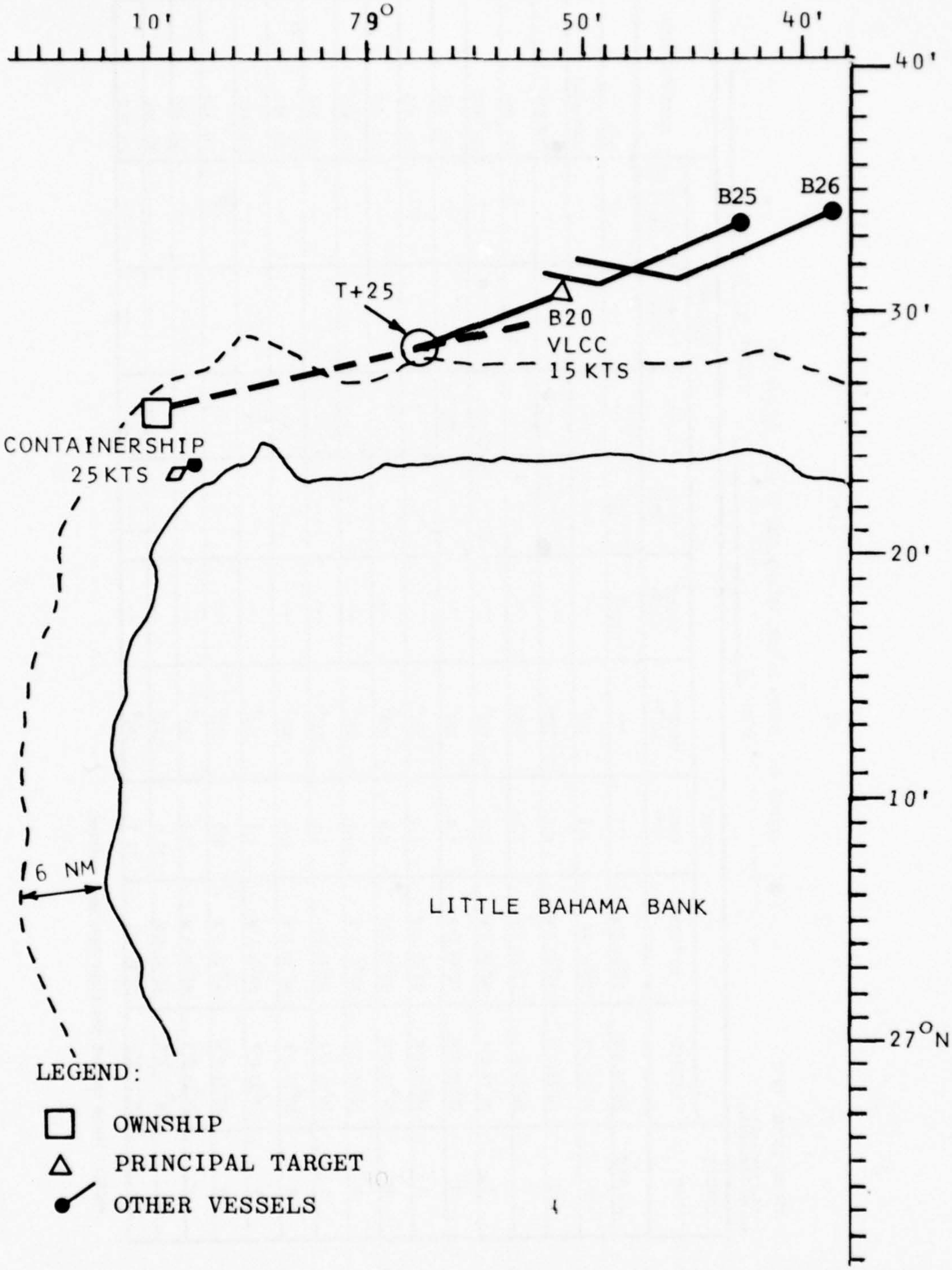


Figure A-16. Matanilla Shoals Watch Segment: B4C (Watch B, Fourth Segment, Containership).

VISUAL CONTACT LIST

TABLE A-1 OPAREA 29°00N, 93°30'W (NW) 27°10'N, 91°30'W (SE)

CONTACT LIST

WATCH: A

SEGMENT: ALL SEGMENTS

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	28°24.8'N	93°04.2'W	---	---	142°	15	---	---	---	VLCC
+00	28°23.4'N	93°03.4W	1.8	159°	---	---	---	---	---	W/OR BUOY
+ 0	28°20.6'N	93°03.6'W	4.0	177°	---	---	---	---	---	RED BUOY
+ 1	28°24'N	93°03.5'W	1.2	159°	---	---	---	---	---	OIL RIG
2	28°22.9'N	92°58.5'W	5.2	112°	---	---	---	---	---	OIL RIG
3	28°22.2'N	92°59.2'W	4.8	122°	---	---	---	---	---	OIL RIG
4	28°21.5'N	93°01.6'W	4.4	152°	---	---	---	---	---	OIL RIG
5	28°21.0'N	93°03.0'W	3.8	164°	---	---	---	---	---	OIL RIG
6	28°25.8'N	92°52.5'W	10.2	085°	---	---	---	---	---	OIL RIG
7	28°31.6'N	92°57.8W	8.6	037°	---	---	---	---	---	OIL RIG
8	28°33.2'N	92°58.9'W	9.4	029°	---	---	---	---	---	OIL RIG
9	28°29.0'N	93°04.5'W	4.4	353°	---	---	---	---	---	OIL RIG
10	28°31.4'N	93°10.4'W	9.0	319°	---	---	---	---	---	OIL RIG
11	28°16.8'N	93°04.0'W	8.5	181°	---	---	---	---	---	OIL RIG
12	28°14.7'N	93°01.6'W	10.4	168°	---	---	---	---	---	OIL RIG
13	28°14.3'N	92°59.6'W	11.3	161°	---	---	---	---	---	OIL RIG

+NOTE: These contact positions have been updated.

VISUAL CONTACT LIST (CONTINUED) TABLE A-1 (cont'd) OPAREA 29°00N, 93°30'W (NW) 27°10'N, 91°30'W (SE)

CONTACT LIST WATCH: A SEGMENT: ALL SEGMENTS

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
14	28°12.8'N	92°58.4'W	13.2	158°	---	---	---	---	---	OIL RIG
15	28°11.0'N	92°56.2'W	15.5	153°	---	---	---	---	---	OIL RIG
16	28°11.6'N	92°40.0'W	25.0	124°	---	---	---	---	---	OIL RIG
17	28°08.6'N	92°58.7'W	17.0	165°	---	---	---	---	---	OIL RIG
18	28°08.5'N	92°55.5'W	17.75	155°	---	---	---	---	---	OIL RIG
19	28°07.6'N	92°54.5'W	19.6	154°	---	---	---	---	---	OIL RIG
20	28°06.5'N	92°55.5'W	20.0	159°	---	---	---	---	---	OIL RIG
+21	28°07.4'N	92°58.7'W	18.4	165°	---	---	---	---	---	OIL RIG
22	28°06.4'N	92°52.6'W	20.8	151°	---	---	---	---	---	OIL RIG
23	28°05.0'N	92°54.2'W	22	157°	---	---	---	---	---	OIL RIG
24	28°05.2'N	92°52.6'W	22.6	153°	---	---	---	---	---	OIL RIG
25	28°03.7'N	92°50.8'W	24.4	150°	---	---	---	---	---	OIL RIG
26	28°02.6'N	92°49.3'W	26.3	148°	---	---	---	---	---	OIL RIG
27	28°01.9'N	92°48.9'W	27	149°	---	---	---	---	---	OIL RIG
28	28°01.4'N	92°47.4'W	28.0	147°	---	---	---	---	---	OIL RIG
29			18.0	099°	---	---	---	---	---	OIL RIG

+NOTE: These contact positions have been updated.

RADAR CONTACT LIST

CONTACT LIST

TABLE A-2 OPAREA 29°00N, 93°30'W (NW) 27°10'N, 91°30'W (SE)

WATCH: A

SEGMENT: ALL SEGMENTS

CONTACT NO.	COMEX						MANEUVERS			CLASSIFICATION
	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	
A			22.8	092°	---	---	---	---	---	OIL RIG
B			23.6	089°	---	---	---	---	---	OIL RIG
C			29.5	105°	---	---	---	---	---	OIL RIG
D			28.0	106°	---	---	---	---	---	OIL RIG
E			26.5	105°	---	---	---	---	---	OIL RIG
F			7.5	262°	---	---	---	---	---	OIL RIG
G			23.0	259°	---	---	---	---	---	OIL RIG
H			6.8	279°	---	---	---	---	---	OIL RIG
I			21.4	195°	---	---	---	---	---	OIL RIG
J			27.5	195°	---	---	---	---	---	OIL RIG
K			27.0	177°	---	---	---	---	---	OIL RIG

CONTACT LIST — TABLE A-3 WATCH: B-MATANILLA SHOAL SEGMENT: ____________

CONTACT NO.	COMEX						MANEUVERS			CLASSIFICATION
	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	
Mantanilla Buoy	27° 23.8'N	79° 07.5'W	39.2	037°	---	---	---	---	---	---
Memory Rock	26° 57.0'N	79° 06.4'W	28	075°	---	---	---	---	---	---
Settlement Point	26° 41.5'N	78° 59.6'W	34	104°	---	---	---	---	---	---
Palmer Beach Radio Tower	26° 43.7'N	80° 02.7'W	24.5	255°	---	---	---	---	---	---

TABLE A-4

CONTACT LIST WATCH: A - GULF PORT SEGMENT: A1V

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	28°24.8'N	93°04.2'W	---	---	142°	15	---	---	---	VLCC
A1 TARGET	28°08.2'N	92°42.4'W	25.6	130°	302.5°	25	---	---	---	CONTAINERSHIP
CHAFF A2 TARGET #2	28°19.1'N	92°55.6'W	11.0	125°	295°	25	T-1/ 8 MIN	322°	25	(CPA IN LANE 1.4) CONTAINERSHIP

TABLE A-5

CONTACT LIST　　　WATCH: A - GULF PORT　　　SEGMENT: A2V

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	$28^{\circ}14.0'$	$92^{\circ}55.11'$	---	---	142°	15	---	----	---	VLCC
A3	$28^{\circ}19.4'$	92.53.33'	5.8	015°	180°	12	44	142°	12	SUPPLY BOAT
A3	PRIOR TO START OF A2V		---	---	264°	12	---	---	---	SUPPLY BOAT
A4	$28^{\circ}13.7'$	$92^{\circ}45.8'$	8.2	093°	285°	5	---	---	---	TUG & TOW
A5	$28^{\circ}9.5'$	$92^{\circ}54.11'$	4.8	172°	274°	8	---	---	---	SUPPLY BOAT
A5	PRIOR TO START OF A2V		---	---	323°	8	---	---	---	
A6	$28^{\circ}8.0'$	$92^{\circ}37.94'$	16.5	100°	291°	12	---	---	---	SMALL TANKER
A7	$28^{\circ}8.2'$	$92^{\circ}42.33$	12.8	116°	352°	15	---	---	---	FISHERMAN
A8	$28^{\circ}4.6'$	$92^{\circ}38.44'$	17.4	121°	323°	10	---	---	---	SMALL TANKER
A9(CHAFF)	$28^{\circ}9.1'$	$92^{\circ}48.88'$	7.3	130°	304°	25	2.5	323°	25	CONTAINERSHIP
	COLLISION @	12 MINUTES								
*A18	$28^{\circ}1.75'$	$92^{\circ}45.9'$	16	138°	314°	25	---	---	---	CONTAINERSHIP
	COLLISION POINT AT T24									
A19	$27^{\circ}58.6'N$	$92^{\circ}35.1'W$	22.9	131°	306°	25	25	323°	25	CONTAINERSHIP

*PRINCIPLE TARGET

TABLE A-6

CONTACT LIST　　　　WATCH: A - GULF PORT　　　　SEGMENT: A3V

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	$28^{o}02.8'N$	$92^{o}45.7'W$	---	---	115^{o}	15	---	---	---	VLCC
A-10 CHAFF	$28^{o}00.7'N$	$92^{o}31.5'W$	12.1	103^{o}	275^{o}	27	*T-9	295^{o}	27	CONTAINERSHIP
	PROJECTED COLLISION AT T-17, PROVIDING NO TARGET MANEUVER, ACTUAL CPA $\approx$ 1.25 NM (±)									
A-11	$27^{o}53.5'N$	$92^{o}17.2'W$	26.7	111^{o}	288.5^{o}	25	---	---	---	CONTAINERSHIP
	PROJECTED COLLISION AT T-40									
A-20	$27^{o}57.2'N$	$92^{o}32.0'W$	15.6	108.5	283^{o}	22.3	15.2	303^{o}	15.2	CONTAINERSHIP

*PRINCIPLE TARGET

the correlation is negative.

+1.00 = a perfect positive correlation
-1.00 = a perfect negative correlation
0.00 = no relationship between variables

Perfect correlations are seldomly obtained in practice. Correlation coefficients between psychological tests and criteria are considered "good" when their absolute magnitudes are above 0.6. A level of significance may be associated with any correlation coefficient, similar to that for other statistical tests. It indicates the probability of obtaining the particular level of correlation by chance; in essence, it represents the confidence placed in the level of correlation obtained.

The z score is used to test the hypothesis about the population correlation coefficient. A table exists that gives the z values that correspond to r values between 0.00 and 1.00. The probability level can then be determined from the corresponding percentile of the particular z value obtained. For example, a significant correlation of -0.63 ($p < 0.05$) was obtained between the post-test score and the mean range standard deviation for each master (see Table 3-6). The magnitude of the correlation is highly negative, denoting a strong correspondence between the post-test score and the consistency of maneuver range (i.e., as post-test scores increase, the mean range standard deviation deviation decreases). The probability level of $p < 0.05$ means that 5 out of 100 times the correlation of -0.63 could occur by chance.

4.1 Spearman's Rank Correlation Coefficient

Nonparametric test used to show the degree of relationship between ranks. The coefficient requires that both variables be measured in at least an ordinal scale so that the objects or individuals under study may be ranked in two ordered series. The value of the coefficient will range from -1.00 to +1.00, using the z score to determine significance, similar to that for the Pearson Product Moment Correlation Coefficient. Whereas the Pearson method considers both direction and magnitude, the Spearman method considers direction only (i.e., rank).

$$r = 1 - \frac{6 \sum D^2}{n(n^2-1)}$$

$$F = \frac{S^2 \text{ between}}{S^2 \text{ within}} \qquad S^2 = \text{variance of sample}$$

The concept of the F test is that if the treatments applied to the different groups have an effect, the between-groups variance will be significantly larger than the variance within each group. The percentiles of the F distribution are used to determine the probability of obtaining a ratio of this size merely by sampling error. One must first select a significance (alpha) level and then determine if the values of F are greater than the values in the F table (i.e., the probability of obtaining this F level by chance). If so, the null hypothesis would be rejected for the particular alpha selected. The analysis of variance is a particularly useful tool. In addition to being relatively powerful, interactive effects and main effects can be evaluated.

For example, using the analysis of variance, a significant difference was found to exist between the mean pre-test and post-test scores for the combined containership and VLCC groups (see Table 3-3).

3.2.1 Test for Heterogeneity of Variance

Assumption underlying the analysis of variance (F test) is that the subjects are drawn from the same general population, and differ only with regard to the experiment treatments; that is, the sample is assumed to be homogeneous, yielding similar group variances. The Hartley Test evaluates whether or not the sample is homogeneous. Hartley's test is based on the statistic F_{max}, the ratio of the largest to the smallest group variance. The distribution of F_{max} depends upon the number of treatments, and the number of degrees of freedom upon which each variance is based. A table giving characteristic values of F_{max} is used to find the rejection level of the homogeneity of variance assumption at the 0.05 significance (alpha) level.

4. CORRELATIONS

A correlation coefficient (r) determines the degree of correspondence between two variables (e.g., two sets of scores or measures). The value of r may range from +1.00 to -1.00. When an increase in one variable tends to be accompanied by an increase in the other variable, the correlation is positive. When the increase in either variable tends to be accompanied by a decrease in the other variable,

c. These populations and the research sample must have the the same variance (or, in special cases, they must have a known ratio of variances).

d. The variables involved must have been measured in at least an interval scale (i.e., a scale which possesses the attributes of magnitude and equal intervals but not an absolute zero point) so that it is possible to use the operations of arithmetic (adding, dividing, finding means, etc.) on the scores.

e. The means of these normal and equally dispersed populations must be linear combinations of effects due to column and/or rows. That is, the effects must be additive.

The parametric tests are often the first choice, since the are generally more powerful than the nonparametric tests. However, the population must possess particular characteristics, as noted above. Violation of these assumptions may affect the different tests in a variety of ways and degrees of seriousness. Descriptions of the parametric tests used in this study follow.

3.1 t Test

A confidence test which depends on the number of degrees of freedom; it is used to determine whether a difference exists between two sample means. The t test is used for samples smaller than 30. For example, the t test showed that the mean number of course changes per maneuver for the VLCC training group was significantly less than the mean number of course changes per maneuver for the VLCC no-training group (see Table 3-7).

3.2 Analysis of Variance

Determines the probability that the means of several groups of scores deviate from one another merely by sampling error. The variance may be based upon the deviation of group means about the grand mean. This is called a between-groups estimate of population variance. Another variance estimate is determined by the deviation of scores within each group about their respective group means. This is known as the within-groups estimate of the population variance. The null hypothesis being tested is, that in the population, all the group means are equal. The variance estimates are distributed as a F function with degrees of freedom equal to the degrees of freedom for numerator and denominator, respectively.

Class	VLCC No-Training (10/48)	Containership Training (2/48)	Totals
Non-Right Maneuvers	A = 10	B = 2	A+B = 12
Right Maneuvers	C = 38	D = 46	C+D = 84
Totals	A+C = 48	B+D = 48	N = A+B+C+D = 96

$$p = \frac{(A+B)!\ (C+D)!\ (A+C)!\ (B+D)!}{N!\ A!\ B!\ C!\ D!}$$

$$p = \frac{(12!)\ (84!)\ (48!)\ (48!)}{(96!)\ (10!)\ (2!)\ (38!)\ (48!)}$$

$$p = 0.02$$

Since the probability level is 0.02, the null hypotheses is rejected. Thus, a significant difference does exist in the non-rignt maneuvers between the VLCC no-training and the containership training groups, with the VLCC no-training group making significantly more non-right maneuvers.

3. PARAMETRIC TESTS

A parametric test is one whose model specifies the following conditions about the characteristics of the population from which the research sample was drawn:

a. The observations must be independent. That is, the selection of any one case from the population for inclusion in the sample must not bias the chances of any other case of inclusion, and the score which is assigned to any case must not bias the score which is assigned to any other case.

b. The observations must be drawn form normally distributed populations.

0.5 and 0.6 might be ranked as 1 and 2 respectively. The determination of a significant difference between the two sample groups is based on the rank present in each group. This test is conservative and convenient to apply. It was used to evaluate differences existing in the mean range standard deviation between the VLCC training and no-training groups (Table 3-4).

2.4 Fisher Exact Probability Test

A nonparametric test which should be used in place of the Chi Square test if the smallest expected frequency is less than five and if the sample size is less than twenty. The Fisher Test is a useful technique for analyzing discrete data (either nominal or ordinal). It is used when the scores from two independent random samples fall into one or the other of two mutually exclusive classes. The scores are represented by frequencies in a 2 x 2 contingency table. The exact probability of the observed occurrence is found by taking the ratio of the product of the factorials of the four marginal totals to the product of the cell frequencies multiplied by N factorial. That is:

$$p = \frac{(A + B)!\ (C + D)!\ (A + C)!\ (B + D)!}{N!\ A!\ B!\ C!\ D!}$$

This test will yield a probability (significance) level which will determine whether the two groups differ significantly in the proportion with which they fall into the two classifications.

For example, the Fisher Test was used, due to a sample size of less than 20, to analyze the proportions of non-right maneuvers. The following provides an example of the employment of the Fisher Test used to test the null hypothesis that there was no difference in non-right maneuvers between the VLCC no-training and the containership training group (see Table 3-7).

The VLCC no-training group had a proportion of 10/48 non-right maneuvers. The containership training group had a proportion of 2/48 non-right maneuvers. To use the Fisher Test, the following matrix was set up:

2.1 Types of Scales

Ratio Scale - any scale of measurement possessing magnitude, equal intervals, and an absolute zero point (e.g., weight).

Interval Scale - possesses the attributes of magnitude and equal intervals, but not an absolute zero point (e.g., age).

Ordinal Scale - reflects only magnitude and does not possess the attributes of equal intervals or an absolute zero point (e.g., IQ).

Nominal Scale - refers to the classification of items into discrete groups which do not bear any magnitude relationships to one another (e.g., marital status).

2.2 Mann Whitney U Test

A nonparametric test which can be used with at least ordinal data. The Mann Whitney U Test may be used to test whether two independent groups have been drawn from the same population. It is one of the most powerful of the nonparametric tests, and it is a most useful alternative to parametric tests of the differences between two means (e.g., when the researcher wishes to avoid parametric tests' assumptions). The Mann Whitney U Test was used to evaluate if the VLCC no-training and VLCC plus containership training groups differed in their mean post-test score (see Table 3-4). This test was used since it is appropriate for comparison of unequal sized groups. The former group consisted of six masters, while the latter consisted of 12 masters. This analysis resulted in rejection of the null hypothesis at a level of $p < 0.01$ (e.g., only 1 out of 100 times would two groups have scores that differed in this manner by chance). Hence, it was concluded that the difference in scores could be attributed to the effectiveness of the training program.

2.3 Rank Sum Test

A nonparametric test used to evaluate the null hypothesis that the medians of two populations are equal. It is not necessary that the samples contain the same number of observations. They must, however, be continuous and have the same form. This test evaluates the data on the basis of their relative rank. It does not consider the magnitude of their differences. For example, the numbers 0.5 and 1.2 might be ranked 1 and 2, respectively; likewise, the numbers

level (alpha or p level) and the statistical test all have an effect on the test's power. The power of a test indicates the probability that the statistical test will yield significant results for a particular experiment when, in fact, the results are significant. For example, an analysis of variance was performed on the post-test scores for the VLCC no-training group and the VLCC training group. The significance level of $p < 0.06$ indicates that the null hypothesis (i.e., that the mean post-test score for the VLCC training group is not significantly greater than the mean post-test score for the VLCC no-training group) will be rejected.

1.7 Degrees of Freedom

The number of degrees of freedom (symbolized by df) for any statistic is the number of components that are free to vary. The number of degrees of freedom equals the number of items in the sample "n", less 1 (i.e., n-1). For example, if the sum of a column of ten numbers is known, up to nine numbers may vary without affecting the sum. The tenth number, however, has to be fixed to maintain the known sum. Hence, 9 degrees of freedom exist. Another example, when an analysis of variance was performed on the post-test scores for the VLCC training versus the VLCC no-training group, an $F = 6.32$ with $df = (1,5)$ was obtained. The 1 and 5 degrees of freedom, (i.e., $df = (1,5)$) respectively, exist because a two-way interaction is present with two variables (i.e., VLCC training and VLCC no-training) interacting with six variables (i.e., post-test scores for six subjects).

2. NONPARAMETRIC TESTS

A nonparametric test is one whose model does not specify conditions (such as normalcy of distribution) about characteristics of the population from which the sample was drawn. Certain assumptions are associated with most nonparametric statistical tests (i.e., that the observations are independent and that the variables under study have underlying continuity, but these assumptions are fewer and much weaker than those associated with parametric tests). Most nonparametric tests apply to data in at least an ordinal scale (i.e., a scale which reflects only magnitude, but does not have to possess the attributes of equal intervals or an absolute zero point), some apply also to data in a nominal scale (i.e., a scale in which items are classified into discrete groups which do not bear any magnitude relationships to one another, e.g., groups based on ethnic origin).

sample (i.e., 18 VLCC and containership masters) would have occurred by chance only 5 out of 100 times. Since a "p" of less than 0.10 was selected as the cut-off, the null hypothesis was rejected, and the alternative hypothesis accepted (i.e., a significant difference in behavior of the two groups was observed). The inference may be drawn therefore, on the basis of these sample results, that the population of all similar masters would make fewer non-right maneuvers in this situation if they participated in the training program.

1.4 Parameter

A parameter designates quantitative characteristics of a population rather than a sample. For a given population, the parameter of interest may also be a mean, the frequency, the proportion of observations, a standard deviation, a correlation, or any other measure that is based upon the complete population. An example of the difference between a statistic and a parameter is that the mean of a sample would be a statistic, whereas the mean of a complete population would be a parameter.

1.5 Significance Level (Critical Level)

Symbolized by alpha (α) is the probability value that forms the boundary between rejecting or accepting the null hypothesis. For example, a significance level (alpha) of 0.05 means that 5 out of 100 times, the data obtained in the experiment could have occurred by chance. In this report, the significance level is shown as a probability level "p".

The minimum acceptable significance level is selected before the experiment is performed, based on a variety of factors associated with the particular experiment. It is an indication of the confidence that can be placed on the findings. The usual minimum acceptable significance level below which the null hypothesis is rejected is 0.1 or 0.05. The null hypothesis is rejected when the calculated significance level for the collected data falls below this minimum acceptable significance level. The alternative hypothesis is then accepted.

1.6 Power of the Test

Symbolized by B, refers to the probability that the particular test used will reject the null hypothesis when that hypothesis is in fact false. The power of a test is considered primarily during the design of the experiment because experiment design along with the number of subjects, the significance

is that the mean of the post-test scores for the VLCC training group is significantly greater than the mean of the post-test scores for the VLCC no-training group.

1.3 Statistics

Statistics are methods used to evaluate quantitative information gathered on a sample (e.g., a group of VLCC ship masters). Through the use of statistical techniques, characteristics of the subject population (e.g., all VLCC masters) may be inferred from the characteristics of a limited size sample (e.g., 12 VLCC masters). A statistic is a characteristic of the sample (e.g., mean) on the basis of which characteristics of the population may be inferred. A sample is generally used to evaluate the population characteristics since it is usually not feasible to observe the total population. Typically, statistical techniques are used to determine if particular conditions (e.g., presence of a right maneuver restriction) have an effect on the behavior of members of the population (e.g., to determine if a right maneuver restriction 4-1/2 miles from ownship position will affect the type of maneuver made in a potential collision situation with another vessel).

The inferences concerning the population are made by testing hypotheses (i.e., the null and alternative hypotheses--see above) about that population, on the basis of observing the sample. The statistical tests may be used to evaluate a variety of sample characteristics (see below). These may include, for example, the sample mean, sample standard deviation, correlations, and frequency of observations. Statistical techniques are used to evaluate the data (e.g., mean) collected on the sample, and thus reach a quantitative estimate of the population characteristics. The quantitative estimate is typically reached by accepting or rejecting the null hypothesis based on the outcome of the statistical tests.

For example, the Fisher Test (a statistical technique) was used to determine if the training and no-training groups behaved differently when a right maneuver restriction was present about 4-1/2 miles from ownship position (see Table 3-7). The Fisher Test was conducted on the sample characteristic (i.e., statistic) of "proportion of non-right maneuvers", comparing the proportions for the two groups (i.e., training and no-training). The results of the test were calculated to be $p = 0.05$. This result can be interpreted as indicating that the obtained differences in the proportions of non-right maneuvers for the two respective groups in this

APPENDIX B

DEFINITIONS ASSOCIATED WITH STATISTICAL METHODS

1. HYPOTHESIS TESTING

A hypothesis is made about a characteristic of the population. Several types of hypotheses can be made. One such hypothesis used in this study was that the mean of the post-test scores for the VLCC no-training group was the same as the mean of the post-test scores for the VLCC training group. The hypothesis is tentatively held to be true, and then data are collected to determine whether the results are likely to occur within the expected range of sampling error. If the results do not deviate markedly from what would be expected on the basis of sampling variations, there is no reason to doubt the validity of the hypothesis previously supposed to be true. If the results do deviate markedly from what would be expected, indications are that the hypothesis is not true. In this latter instance, the hypothesis would then be rejected.

Typically, there are two types of hypotheses used in the statistical analysis of experiments: 1) the null hypothesis which assumes that there is no difference in performance due to the experiment conditions like the above example; and 2) the alternative hypothesis which assumes that a difference in performance does exist.

The following definitions further describe the statistical acceptance and rejection of hypotheses.

1.1 Null Hypothesis

The hypothesis that is tentatively held to be true (i.e., that there is no difference between performance obtained under different experiment conditions). The null hypothesis is customarily symbolized by H_0. Statistical tests attempt to disprove the null hypothesis. An example of a null hypothesis which was disproved was that the mean of the post-test scores for the VLCC no-training group is the same as the mean of the post-test scores for the VLCC training group.

1.2 Alternative Hypothesis

The hypothesis that the experimenter is willing to accept if he rejects the null hypothesis. The alternative hypothesis is symbolized by H_1. An example of an alternative hypothesis

TABLE A-19

CONTACT LIST

WATCH: MATANILLA SHOAL

SEGMENT: B4C

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	24°25.7'N	79°13.3'W	---	---	078°	25	---	---	---	CONTAINERSHIP
* B-20	27°31.2'N	78°53.2'W	18.6	075°	250°	15	---	---	---	VLCC
B-25	27°32.5'N	78°46.0'W	24.7	072°	245°	16	27.5	280°	16	VLCC
B-26	27°33.8'N	78°41.0'W	29.2	073°	245°	15	35.7	280°	15	VLCC

TABLE A-18

CONTACT LIST

WATCH: B-MATANILLA SHOAL

SEGMENT: B3C

CONTACT NO.	COMEX							MANEUVERS			CLASSIFICATION
	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	
OWN SHIP	$27^o08.9'N$	$79^o23.0'W$	---	---	030^o	25	---	---	---	CONTAINERSHIP
B-14	$27^o26.6'N$	$79^o13.9'W$	19.5	024^o	175^o	22	---	---	---	60 FT M/V SPORTS FISHERMAN
B-15	$27^o21.4'N$	$79^o19.2'W$	13.3	015^o	262^o	8	---	---	---	TUG & TOW
B-16	$27^o22.8'N$	$79^o19.0'W$	14.6	016^o	000^o	15	---	---	---	FREIGHTER
B-17	$27^o15.8'N$	$79^o25.5'W$	7.3	341^o	035^o	12	---	---	---	TANKER
B-18	$28^o14.6'N$	$79^o12.0'W$	11.4	059^o	052^o	6	---	---	---	SAILBOAT
* B-19	$27^o34.2'N$	$79^o11.7'W$	26.4	022^o	190^o	15	---	---	---	CONTAINERSHIP
B-23	$27^o25.1'N$	$79^o17.8'W$	17.1	019^o	180^o	22	17.6	262^o	22	VLCC
B-24	$27^o39.7'N$	$79^o17.2'W$	31.6	011.5^o	161^o	15	42.8	212^o	15	VLCC

TABLE A-17

CONTACT LIST WATCH: B-MATANILLA SHOAL SEGMENT: B2C

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	$26^{o}48.9'N$	$79^{o}35.4'W$	---	---	030^{o}	25	---	---	---	CONTAINERSHIP
* B-12	$27^{o}16.5'N$	$79^{o}24.1'W$	29.4	020^{o}	185^{o}	15	---	---	---	VLCC*
B-13	$27^{o}00.9'N$	$79^{o}33.9'W$	12	007^{o}	151^{o}	16	08	180^{o}	16	VLCC
B-22	$27^{o}04.8'N$	$79^{o}30.6'W$	17.1	021^{o}	185^{o}	15	17	222^{o}	15	VLCC

*PRINCIPLE TARGET

AD-A071 056 NATIONAL MARITIME RESEARCH CENTER KINGS POINT NY F/G 17/7
RULES OF THE ROAD TRAINING INVESTIGATION.(U)
NOV 78 P ARANOW, T J HAMMELL, M POLLACK MIPR-Z-70099-7-72541

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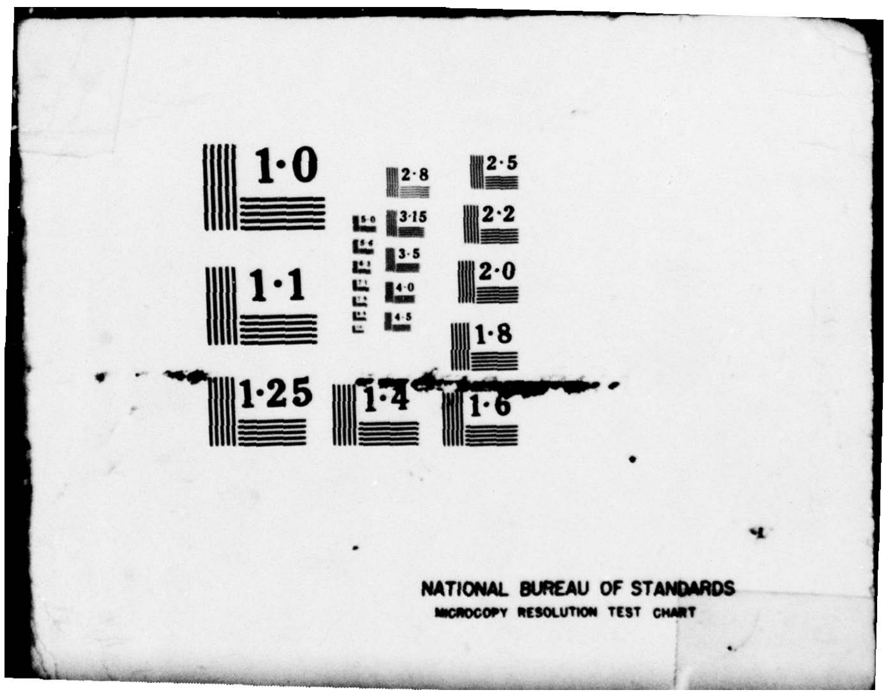
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1·6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

TABLE A-16

CONTACT LIST | WATCH: B-MATANILLA SHOAL | SEGMENT: B1C

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	26°29.1'N	79°49.6'W	---	---	030°	25	---	---	---	CONTAINERSHIP
* + B-1	26°42.2'N	79°40.5'W	14.6	026°	202°	15	---	---	---	VLCC*
B-2	26°37.9'N	79°34.7'W	15	054°	030°	12	40	90	12	
B-3	26°38.8'N	79°30.7'W	19	056°	025°	14	*	---	---	
B-4	26°33.5'N	79°40.6'W	9	060°	200°	8	---	---	---	
B-5	26°36.3'N	79°50.7'W	7.2	353°	215°	10	---	---	---	TANKER (28K)
B-6	26°34.3'N	79°46.6'W	6	026°	342°	27	---	---	---	CONTAINERSHIP
B-7	26°45.5'N	79°48.7'W	15.6	359°	130°	6	---	---	---	
B-8	26°47.2'N	79°39.9'W	19.8	023°	285°	18	---	---	---	
B-9	26°47.5'N	79°35.9'W	21.6	032°	105°	6	---	---	---	TUG & TOW
B-10	26°31.9'N	79°52.5'W	3.8	317°	180°	12	---	---	---	
B-11	26°51.3'N	79°32.6'W	26.2	033°	285°	11	---	---	---	
B-21	26°51.6'N	79°39.1'W	23.9	022°	190°	15	27	225	15	VLCC

*PRINCIPLE TARGET   +NOTE: These contact positions have been updated.

TABLE A-15

CONTACT LIST WATCH: B- MATANILLA SHOAL SEGMENT: B4V

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
Ownship	27° 26.2'N	79° 11.2'W	---	---	075°	15	---	---	---	VLCC
*B20	27° 32.5'N	78° 51.6'W	18.5	070°	247°	25	---	---	---	CONTAINERSHIP
B25	27°34.7'N	78°46.5'W	23.4	068°	244°	24	27.5	260°	24	CONTAINERSHIP
B26	27°36.0'N	78°43.2'W	26.4	068°	245°	21	37	260°	21	CONTAINERSHIP

* Principle Target

TABLE A-14

CONTACT LIST — WATCH: B- MATANILLA SHOAL — SEGMENT: B3V

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
Ownship	27° 14.4'N	79° 19.2'W	---	---	030°	15	---	---	---	VLCC
B14	27° 26.6'N	79° 13.9'W	12.9	019°	175°	22	---	---	---	SPORT FISHERMAN
B15	27° 21.4'N	79° 19.2'W	7	000°	262°	8	---	---	---	TUG & TOW
B16	27° 22.8'N	79° 19.0'W	8.4	005°	000°	15	---	---	---	FREIGHTER
B17	27° 15.8'N	79° 25.5'W	5.8	281°	035°	12.0	---	---	---	TANKER
B18	27° 14.6'N	79° 12.0'W	6.3	088°	052°	6	---	---	---	SAILBOAT
*B19	27° 39.6'N	79° 10.1'W	26.4	018°	190°	25	---	---	---	CONTAINERSHIP
B23	27°31.2'N	79°15.5'W	17.6	011°	180°	27	17	206	27	CONTAINERSHIP
B24	27°44.8'N	79°19.5'W	30.9	000°	161.5°	24	43	197°	24	CONTAINERSHIP

* Principle Target

TABLE A-13

CONTACT LIST

WATCH: B- MATANILLA SHOAL

SEGMENT: B 2V

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
Ownship	27° 00.9'N	79° 27.6'W	---	---	030°	15	---	---	---	VLCC
*B12	27° 29.7'N	79° 19.4'W	29.2°	014°	184°	25	---	---	---	CONTAINERSHIP
B13	27° 13.7'N	79° 28.9'W	17.7°	013°	185°	27	17	215	27	CONTAINERSHIP
(Chaff)										

* Principle Target

TABLE A-12

CONTACT LIST WATCH: B-MATANILLA SHOAL SEGMENT: B1V

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
Ownship	26° 49.6'N	79° 34.3'W	---	---	030°	15	---	---	---	VLCC
*B1	27° 02.8'N	79° 27.0'W	14.8	026°	204°	25	---	---	---	CONTAINERSHIP
B2	26° 55.4'N	79° 22.4'W	12	062°	030°	12	40	090	12	FISHERMAN
B3	26° 57.2'N	79° 16.7'W	16	062°	025°	14	20	075	14	FISHERMAN
B4	26° 51.1'N	79° 27.3'W	6.5	076°	200°	8	---	---	---	FISHERMAN
B5	26° 53.0'N	79° 37.2'W	5	328°	215°	10	---	---	---	TANKER (28k)
B6	26° 51.2'N	79° 33.0'W	8	020°	342°	27	20	000	27	CONTAINERSHIP
B7	27° 02.4'N	79° 36.5'W	12.8	352°	128°	6	---	---	---	COASTER
B8	27° 05.0'N	79° 27.6'W	16.6	021°	285°	18	---	---	---	TANKER
B9	27° 05.2'N	79° 25.1'W	18.4	031°	105°	6	---	---	---	TUG & TOW
B10	26° 49.6'N	79° 36.8'W	4	270°	180°	12	---	---	---	FREIGHTER
B11	27° 8.5'N	79° 21.4'W	22.9	032°	285°	11	---	---	---	FREIGHTER
B21	27°8.8'N	79°27'W	20.1	019°	190°	18	25	215	18	VLCC

* Principle Target

TABLE A-11

CONTACT LIST — WATCH: A - GULF PORT — SEGMENT: A4C

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	27° - 44'N	92° - 14.3'W	--	--	115°	25	--	--	--	CONTAINERSHIP
CHAFF - 1 A-12	27° - 41.0'N	92° - 01.2'W	7.8	105°	266°	15	3	295°	15	VLCC
	PROJECTED COLLISION T-19 PROVIDED NO TARGET MANEUVER ACTUAL CPA = 1.25 NM±									VLCC
CHAFF - 2 A-13	27° - 38.4'N	91° - 53.6'W	14.9	107°	272°	15	12	295°	15	VLCC
	PROJECTED COLLISION T-30 PROVIDED NO TARGET MANEUVER ± ACTUAL CPA = 1NM±									VLCC
A-14*	27° - 34.3'N	91° - 44.2'W	28.8	107°	273°	15	--	--	--	VLCC
			PROJECTED	COLLISION	T-44					
A-15	27° - 35.7'N	92° - 02'W	14	126°	150°	14	--	--	--	SHRIMPER
A-16	27° - 38'N	92° - 03.1'W	12	120°	252°	9	40	265°	9	LARGE TANKER 38K DWT
A-17	27° - 50.4'N	92° - 04.6'W	14.2	140°	272°	12	--	--	--	SMALL TANKER 22K DWT

TABLE A-10

CONTACT LIST

WATCH: A - GULF PORT

SEGMENT: A3C

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	27^{o} - 53.8'N	92^{o} - 36.8'W	--	--	115^{o}	25	--	--	--	CONTAINERSHIP
CHAFF A-10	27^{o} - 50'N	92^{o} - 23.6'W	12.4	106^{o}	275^{o}	15	9	295^{o}	15	VLCC
	PROJECTED COLLISION AT T+18		PROVIDING	NO TARGET MANEUVER, ACTUAL		CPA 1.2 NM	($\pm$)			
A-11	27^{o} - 43.6'N	92^{o} - 9.9'W	26.4	111^{o}	287^{o}	15	--	--	--	VLCC
	PROJECTED COLLISION AT T+40									
A-20	27^{o}48.1'N	92^{o}19.5'W	16.5	110^{o}	280^{o}	15	14	295^{o}	15	VLCC

TABLE A-9

CONTACT LIST | WATCH: A - GULF PORT | SEGMENT: A2C

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	28°-12.0'N	92°-53.3'W	---	---	142°	25	---	---	---	CONTAINERSHIP
A-3	28°-14.4'N	92°-48.9'W	4.6	057°	180°	12	44	142°	12	SUPPLY BOAT
A-3	PRIOR TO START OF		A2V	---	264°	12	---	---	---	SUPPLY BOAT
A-4	28°-08.7'N	92°-41.4'W	11.4	110°	285°	5	---	---	---	TUG AND TOW
A-5	28°-4.5'N	92°-49.7'W	8.6	159°	274°	8	---	---	---	SUPPLY BOAT
A-5	PRIOR TO START OF		A2V	---	323°	8	---	---	---	SUPPLY BOAT
A-6	28°-3.0'N	92°-33.5'Q	20	76°	291°	12	---	---	---	SMALL TANKER
A-7	28°-3.2'N	92°-37.9'W	16.6	122°	352°	15	---	---	---	FISHERMAN
A-8	27°-59.6'N	92°-34.0'W	21.1	125°	323°	10	---	---	---	SMALL TANKER
CHAFF A-9	28°-04.3'N	92°45.0'W	8.7	132°	302°	17	---	---	---	VLCC
	COLLISION AT 16 MINUTES						2.5	323°	17	VLCC
*A-18	27°-59.6'N	92°-42.2'W	16	139.5°	316°	15	---	---	---	VLCC
A-19	27°56.4'N	92°35.3'W	21.9	134.7°	303°	15	25	323°	15	VLCC

* PRINCIPLE TARGET

TABLE A-8

CONTACT LIST — WATCH: A - GULF PORT — SEGMENT: A1C

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	28^{o} - 28'N	93^{o} - 6.2'W	--	--	142^{o}	25	--	--	--	CONTAINERSHIP
TARGET	28^{o} - 12'N	92^{o} - 48.6'W	25.6	135^{o}	302^{o}	15	--	--	--	VLCC
CHAFF +TARGET#1	28^{o} - 24.6'N	92^{o} - 59.5'W	10	125^{o}	281^{o}	15	8 min.	322^{o}	15	CPA 1.4 VLCC IN LANE

+NOTE: These contact positions have been updated.

TABLE A-7

CONTACT LIST — WATCH: A - GULF PORT — SEGMENT: A4V

CONTACT	COMEX						MANEUVERS			
NO.	LATITUDE	LONGITUDE	RANGE (NM)	BEARING (DEG)	COURSE (DEG)	SPEED (KTS)	TIME	COURSE (DEG)	SPEED (KTS)	CLASSIFICATION
OWN SHIP	27°56.8'N	92°31.1'W	---	---	115°	15	---	---	---	VLCC
CHAFF A-12	27°55.8'N	92°22.3'W	8.25	098°	268°	27	*T-4	295°	27	CONTAINERSHIP
	*PROJECTED COLLISION AT T-12 PROVIDED NO TARGET MANEUVER, ACTUAL CPA ≈ 1.25 NM (±)									
CHAFF-2 A-13	27°54.2'N	92°15.4'W	14.75	101°	271°	24	*T-13	295°	24	CONTAINERSHIP
	*PROJECTED COLLISION AT T-23 PROVIDED NO TARGET MANEUVER, ACTUAL CPA ≈ 1.25 NM (±)									
A-14	27°51.7'N	92°59.9'W	28.8	100°	272°	25	---	---	---	CONTAINERSHIP
	PROJECTED COLLISION AT T-44									
A-15	27°51.8'N	92°25.8'W	7	138°	150°	14	---	---	---	SHRIMPER
A-15	27°39.9'N	92°21.4'W	31.5	138°	340°	14	T-3 55 MIN	150°	14	SHRIMPER
A-16	27°54.0'N	92°26.9'W	4.8	129°	252°	9	T-40	265°	9	LARGE TANKER 38K DWT
A-17	27°49.2'N	92°28.6'W	8.2	164°	272°	12	---	---	---	SMALL TANKER 22K DWT

*PRINCIPLE TARGET

Where:

n = number of paired observations

D^2 = squared difference between the ranks for a given subject in the two series.

4.2 Pearson Product Moment Correlation

This parametric test takes into account the relative magnitude differences in the data being evaluated. Similar to the Spearman Rank Correlation Coefficient, the Pearson values range from -1.00 to +1.00. This test is preferred when a ratio scale is used. The variables evaluated in Table 3-5 were all on a ratio scale.

4.3 Split-Half Reliability Coefficient

Coefficient of reliability obtained by correlating scores on one half of a test with scores on the other half. The Spearman Brown formula is usually applied to adjust for the doubled length of the test. The two halves may consist of odd-numbered and even-numbered items or the first half and second half of the test. The split-half test measures the internal consistency of a test.

References

Edwards, Allen L. "Experimental Design in Psychological Research," New York: Holt, Rinehart and Winston, Inc., 1963.

McCall, Robert B. "Fundamental Statistics for Psychology," New York: Harcourt, Brace and World, Inc. 1970.

Mehrens, William A. and Lehmann, Irvin J. "Measurement and Evaluation in Education and Psychology." New York: Holt, Rinehart and Winston, Inc. 1973.

Siegel, Sidney. "Nonparametric Statistics for the Behavioral Sciences." New York: McGraw-Hill Book Company Inc., 1956.

APPENDIX C

GROUND TRACK PLOTS

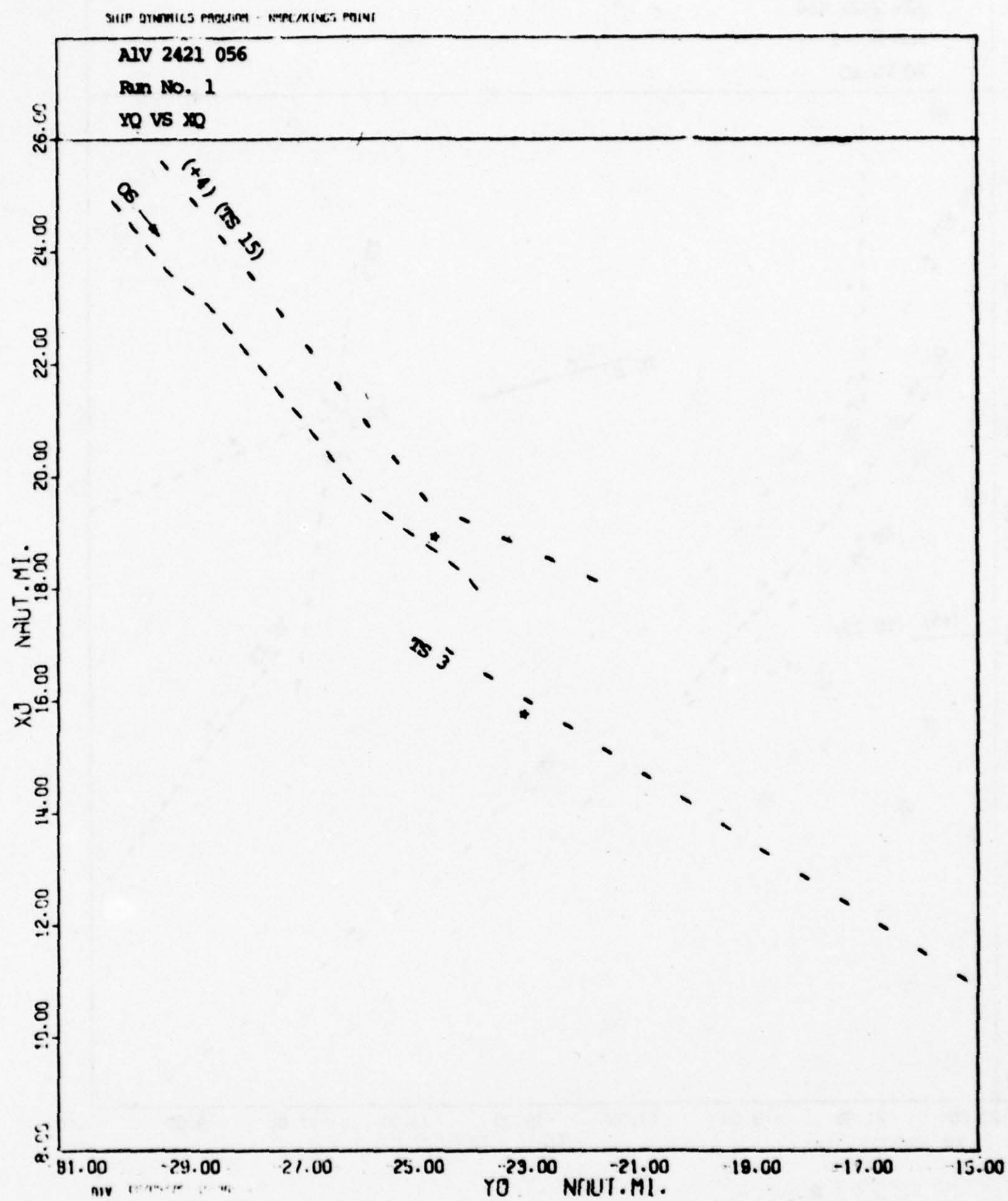
The ground track plots presented in this appendix depict all of the 144 experimental runs made by the 18 subjects during the Rules of the Road Training Investigation. The scales of the plots are Y_O and X_O, an arbitrary machine coordinate system, measured in nautical miles.

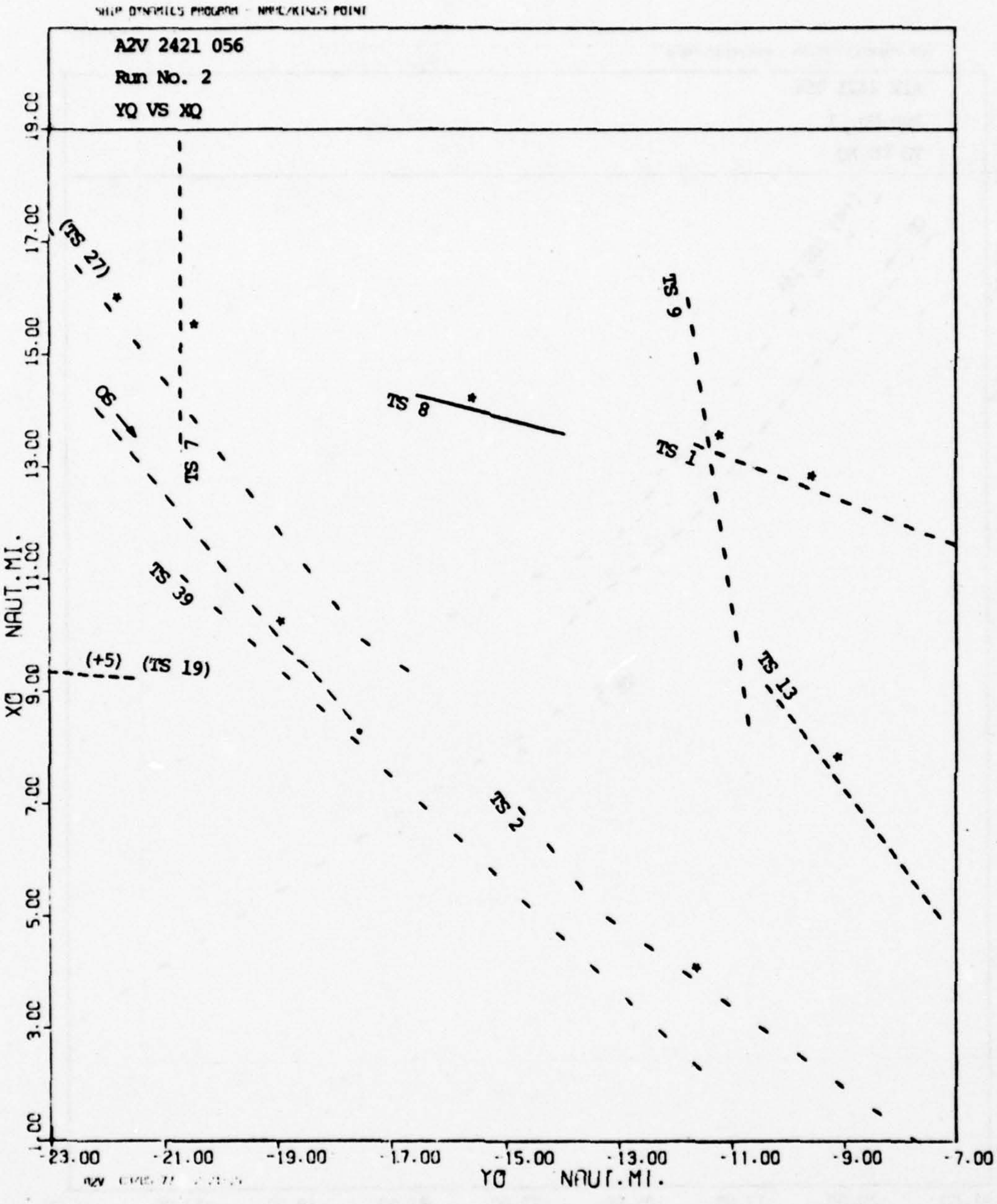
Each plot is identified in the upper left corner with key information contained in a 10 character alphanumeric, presented in groupings of 3, 4, and 3. The first grouping identifies the watch, the watch segment, and the class of ship; for example A1V - Gulf watch(A), first of four segments (1), for a VLCC watch officer(V). The B watch is in the Florida Straits, it is also divided into four segments, and a containership mariner is signified by the letter "C". The last three numerics run from 056 to 074 and represent the subject's identification number. The middle four numerics are a CAORF internal identification of the computer playback tape number.

Ship tracks, for both ownship and target ships are made up of a series of ship positions presented at 2-minute intervals. Each track has an asterisk placed next to a ship position which represents the same point of time in the run. That time is at or near the time ownship was expected to maneuver. On those target-ship tracks that continue beyond the illustration limits, the ship position bearing the asterisk might not appear; for those tracks, a number in parentheses (for example +4) appears near the last ship representation to indicate the additional number of ship positions (in this example, 8 minutes later) that would have had to be included to show the one bearing the asterisk.

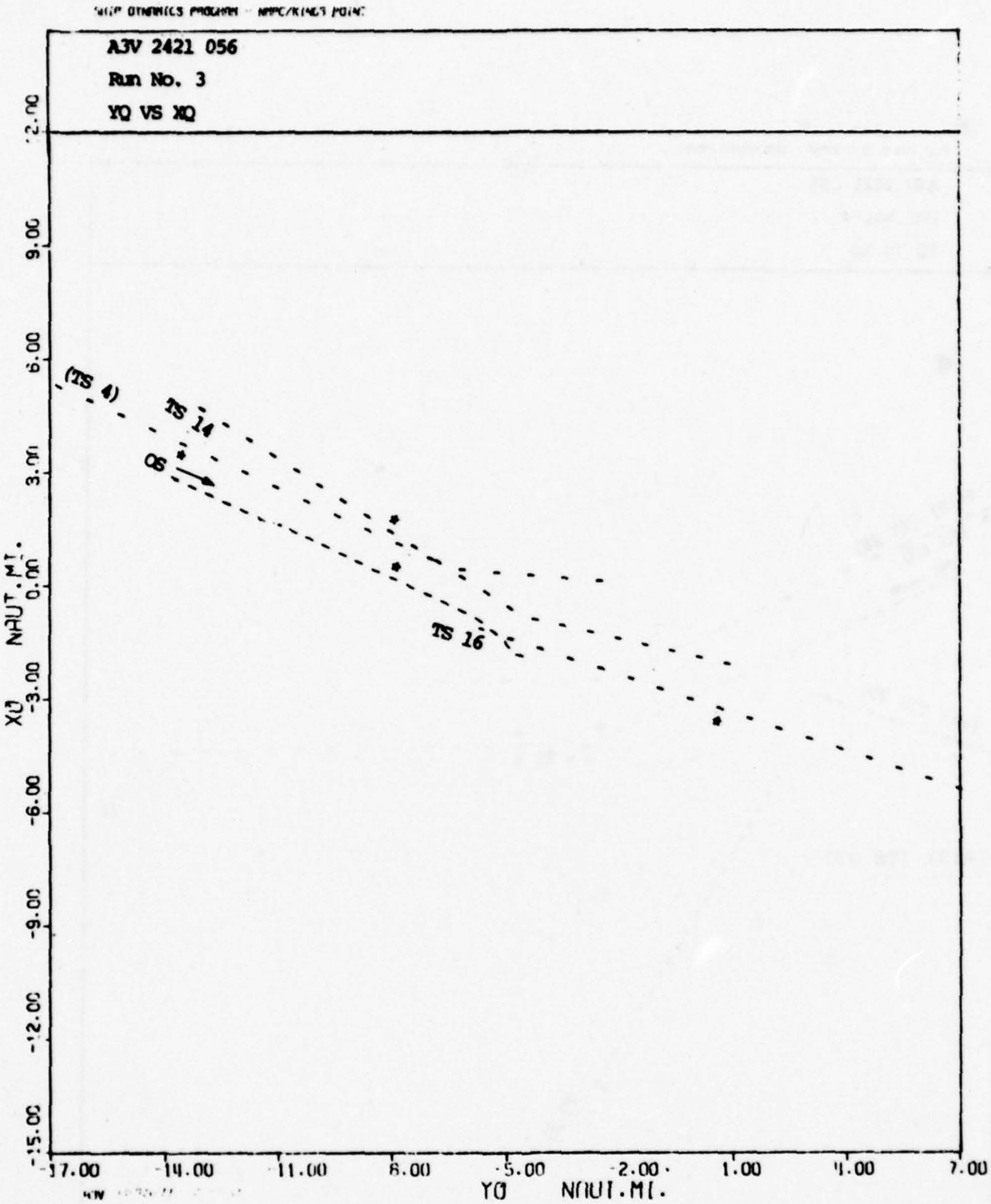
Ownship for the A watches were on a course of approximately 115-142°, starting from the upper left portion of the plot and proceeding to the lower right. The B watches were on a course of 30-75°, starting from the lower left and proceeding towards the upper right. Target tracks can normally be identified by the straightness of their track (chaff targets contain two straight segments), and an identification, such as TS3 (Target Ship #3), which is placed at the last target ship shown in a plot. On those target ship tracks that continue beyond the illustration limits, the target ship designation appears in parentheses near the last ship position that is included. Ownship has an "O.S." placed near the start of track.

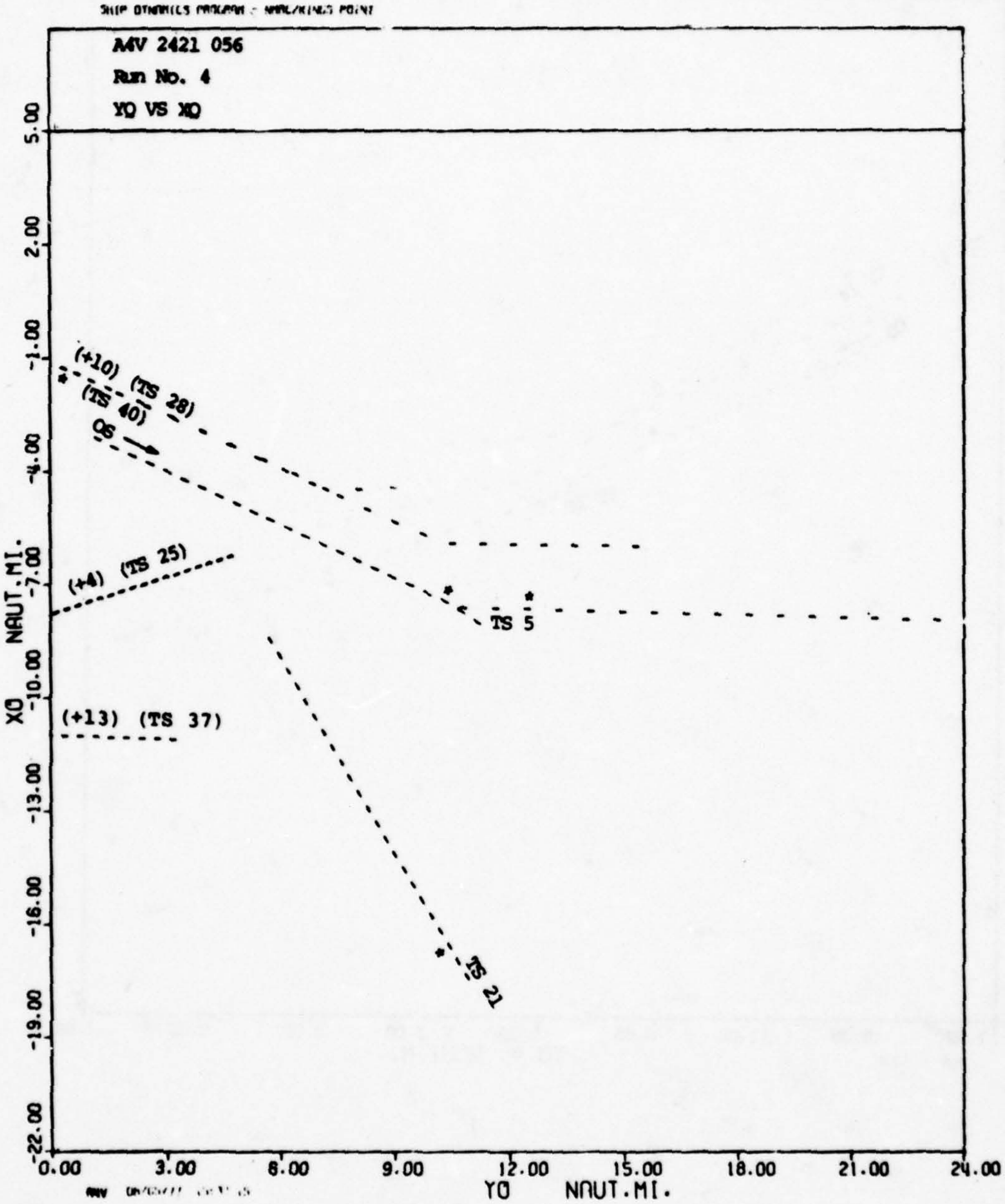
These ground plots have been developed from the superposition of the actual ownship plot to the end of the run and a fixed overlay of target ships; therefore the last ship position for ownship, which varies from run to run of a given watch segment, does not necessarily represent the same point in time as the last positions shown for target ships, which do not vary. To reemphasize, the start of all tracks represent the same time in the run, the asterisks represent the same time on each track, but the last plotted position of ownship does not necessarily represent the same point in time as the last target ships shown.


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
AIV 2421 056
Run No. 1
YO VS XO
OS
(+4) (TS 15)
TS 3
XO NAUT.MI.
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
-15.00
YO NAUT.MI.

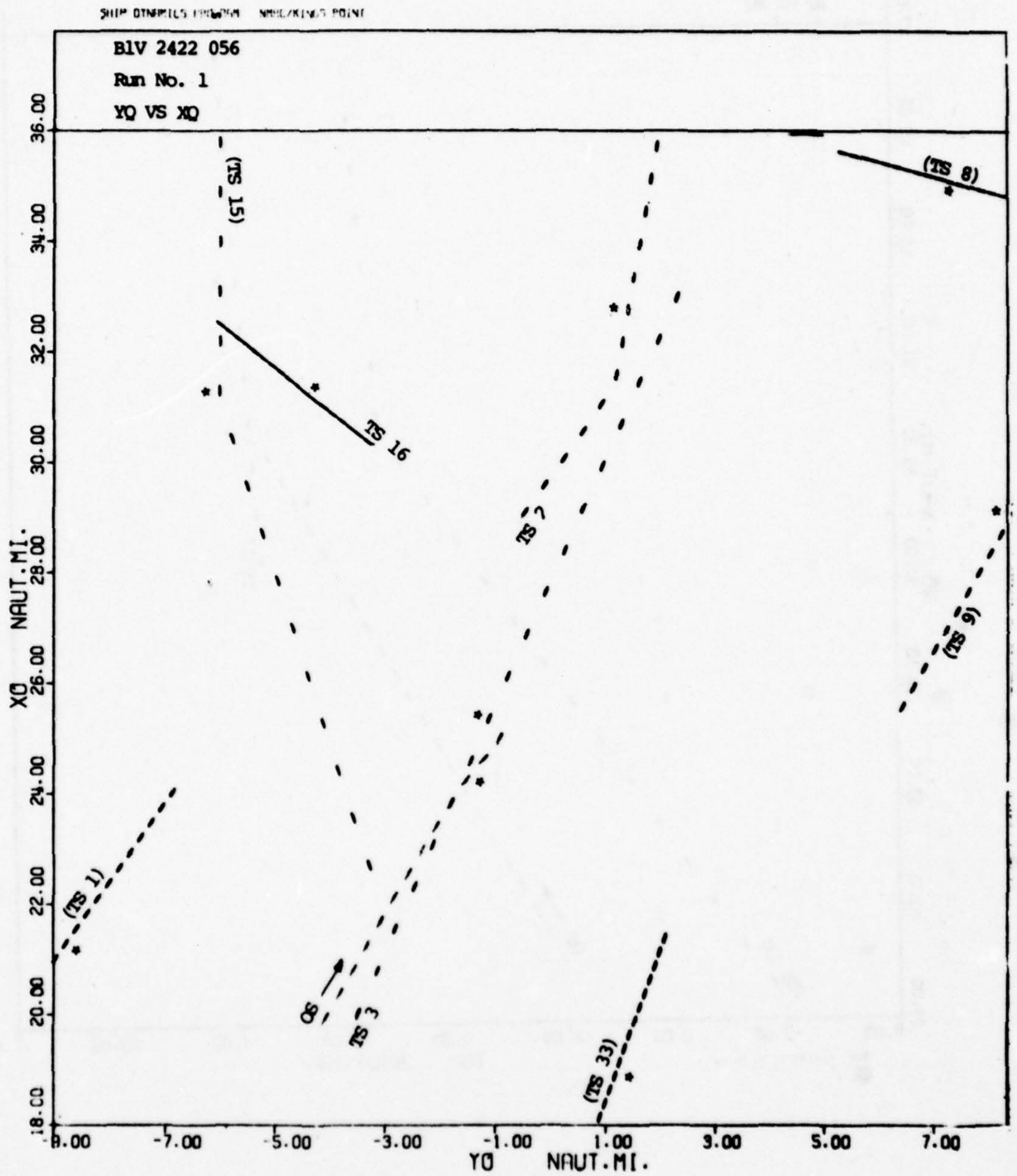


A2V 2421 056
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-23.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
(TS 27)
TS 7
TS 8
TS 9
TS 1
OS
TS 39
(+5)
(TS 19)
TS 13
TS 2

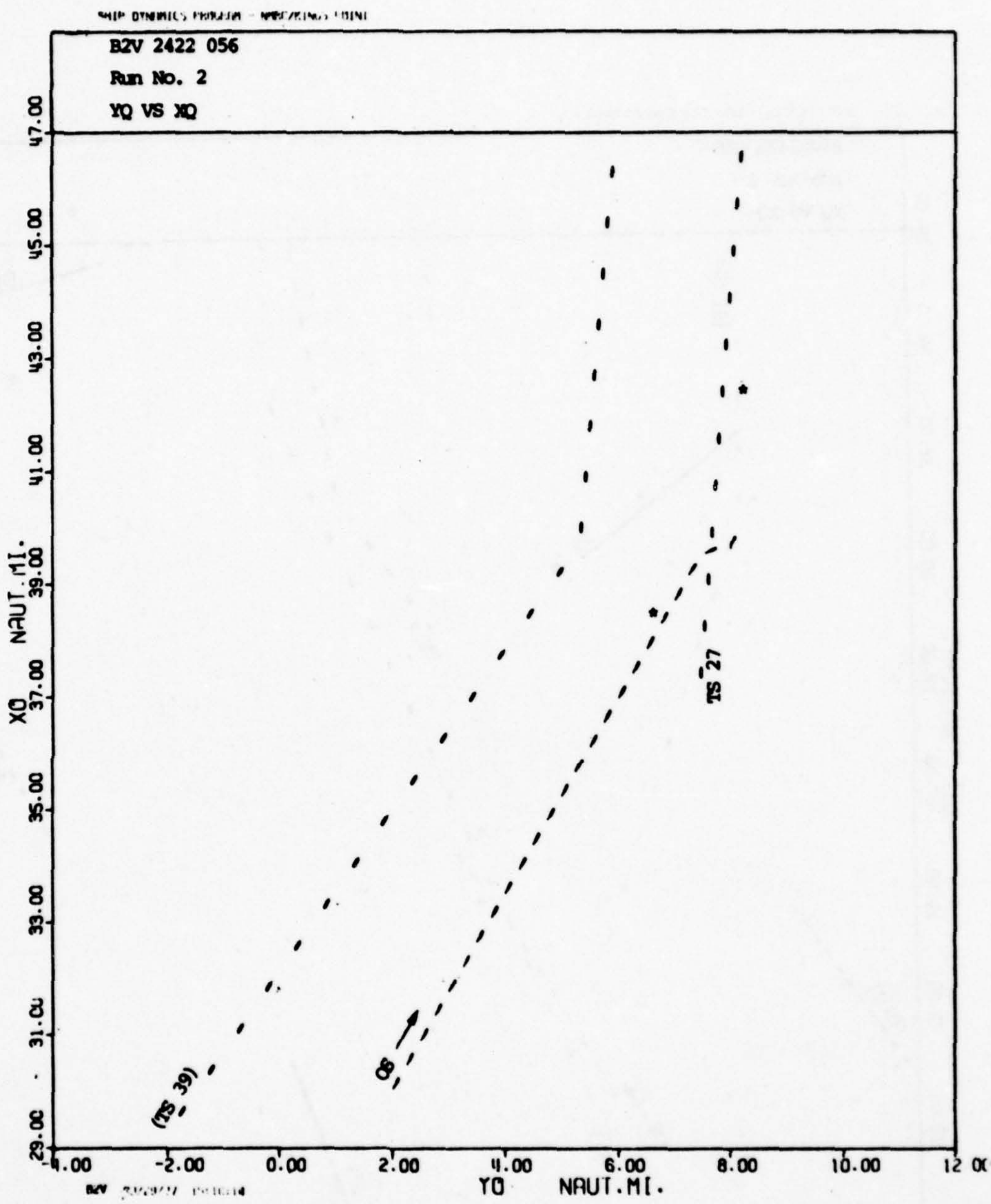

A3V 2421 056
Run No. 3
YQ VS XQ
(TS 4)
TS 14
OS
TS 16
XQ NAUT.MI.
YQ NAUT.MI.
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-17.00
-14.00
-11.00
-8.00
-5.00
-2.00
1.00
4.00
7.00

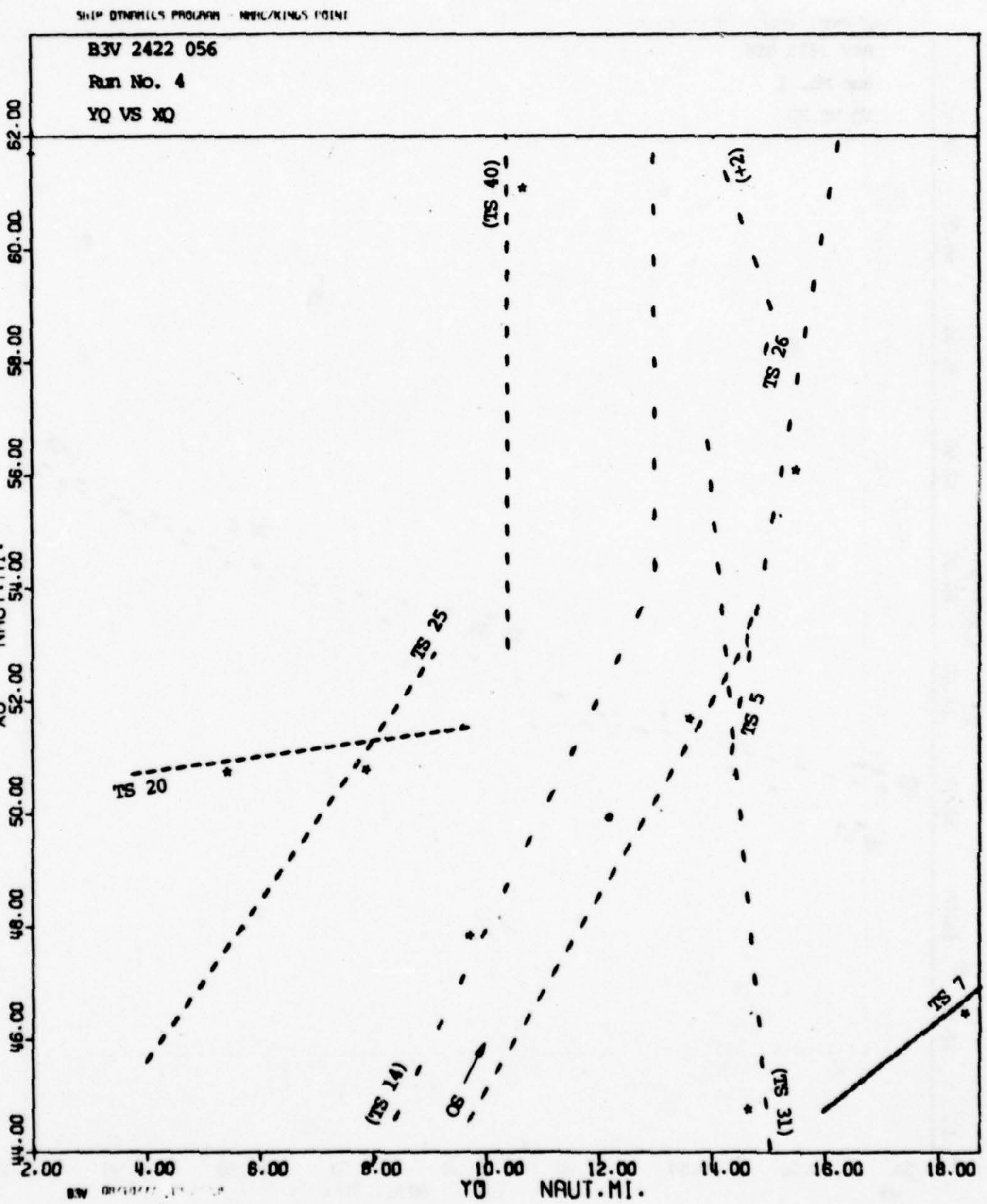


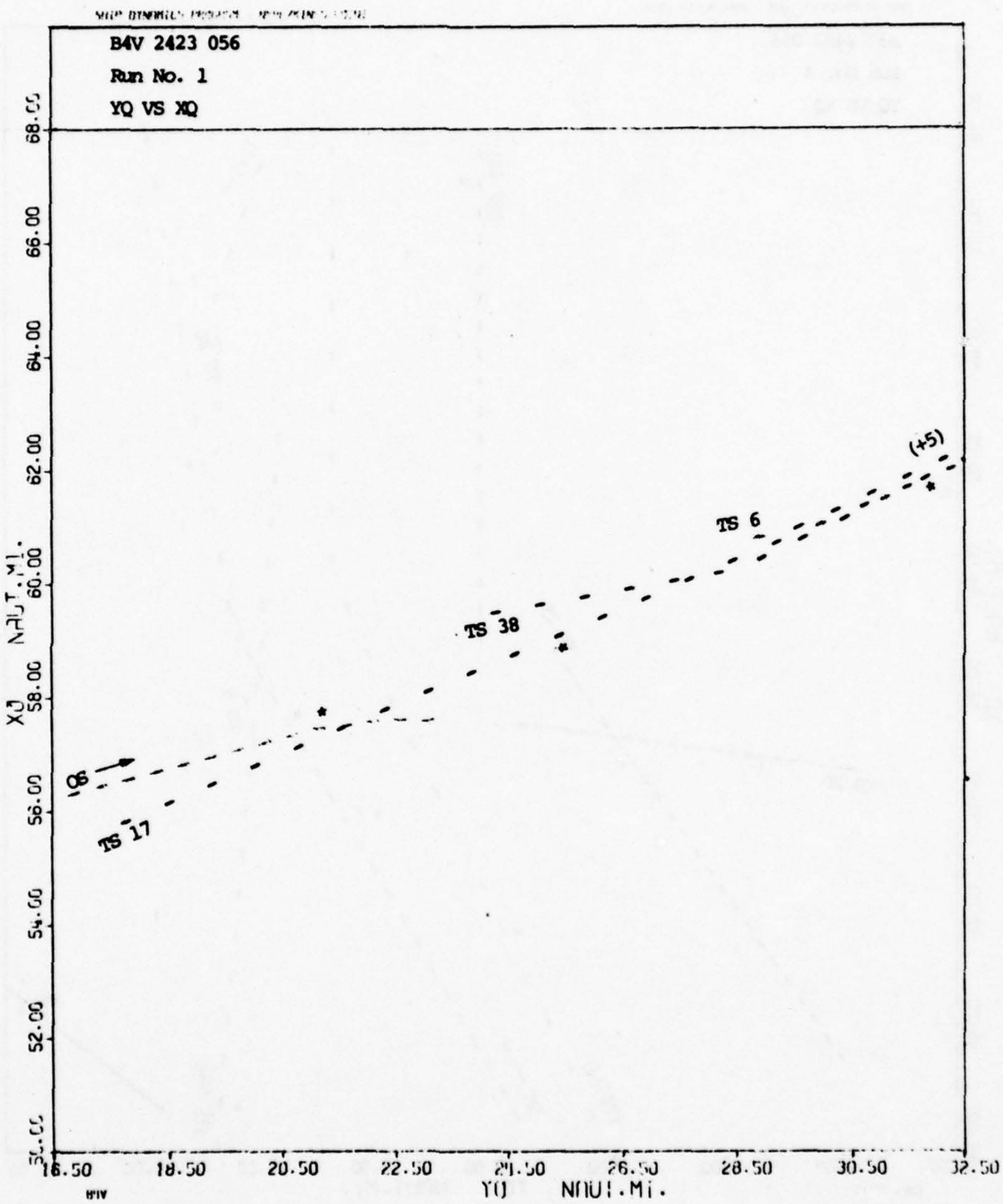
A4V 2421 056
Run No. 4
XO VS XO
(+10) (TS 28)
(TS 40)
OS
(+4) (TS 25)
TS 5
(+13) (TS 37)
TS 21
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
XO NAUT.MI.
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
YO NAUT.MI.

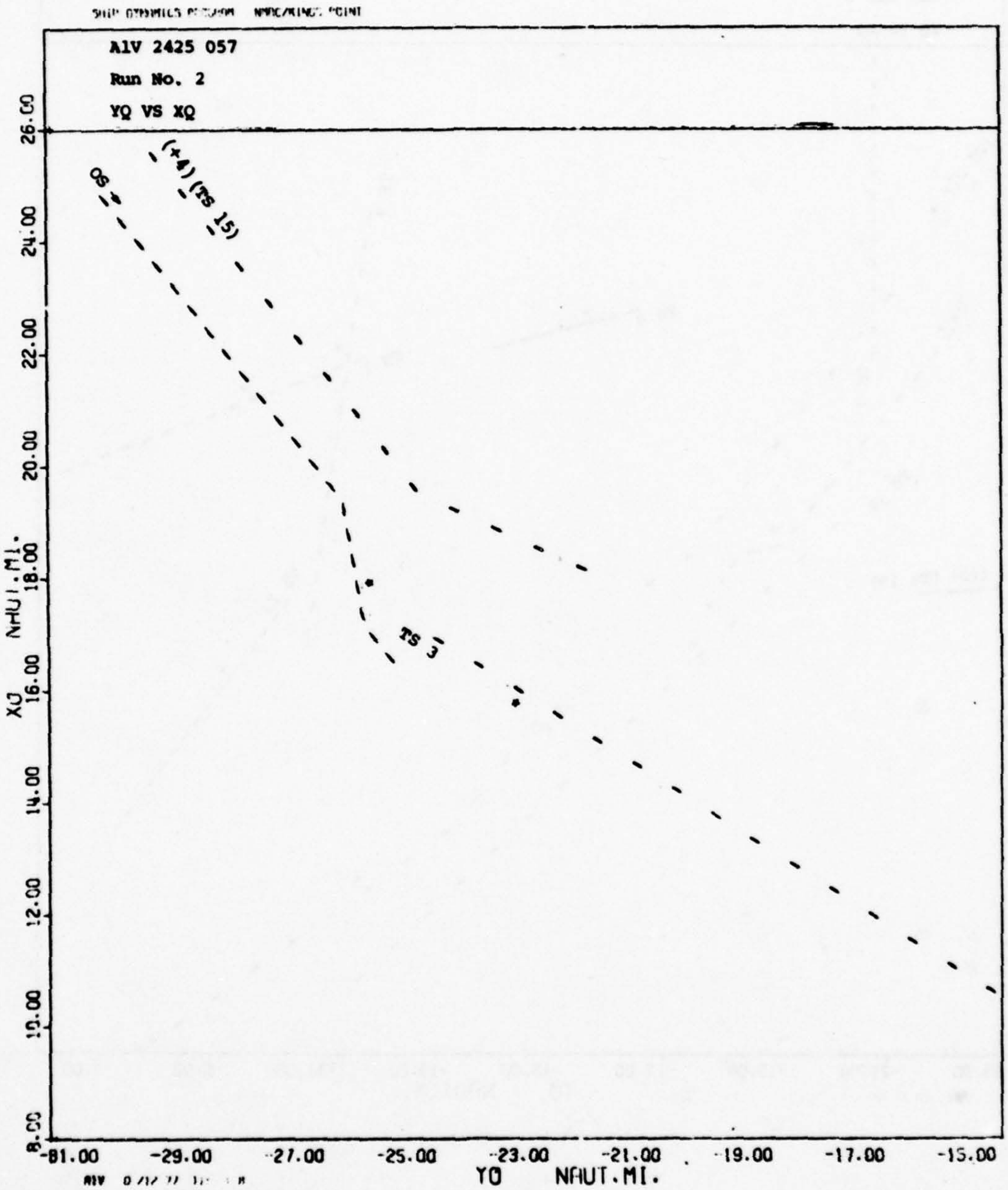


SHIP DYNAMICS PROGRAM NMRC/KINGS POINT
B1V 2422 056
Run No. 1
YO VS XO
XO NAUT.MI.
YO NAUT.MI.
(TS 15)
TS 16
(TS 8)
TS 7
(TS 9)
(TS 1)
OS
TS 3
(TS 33)
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
-9.00
-7.00
-5.00
-3.00
-1.00
1.00
3.00
5.00
7.00

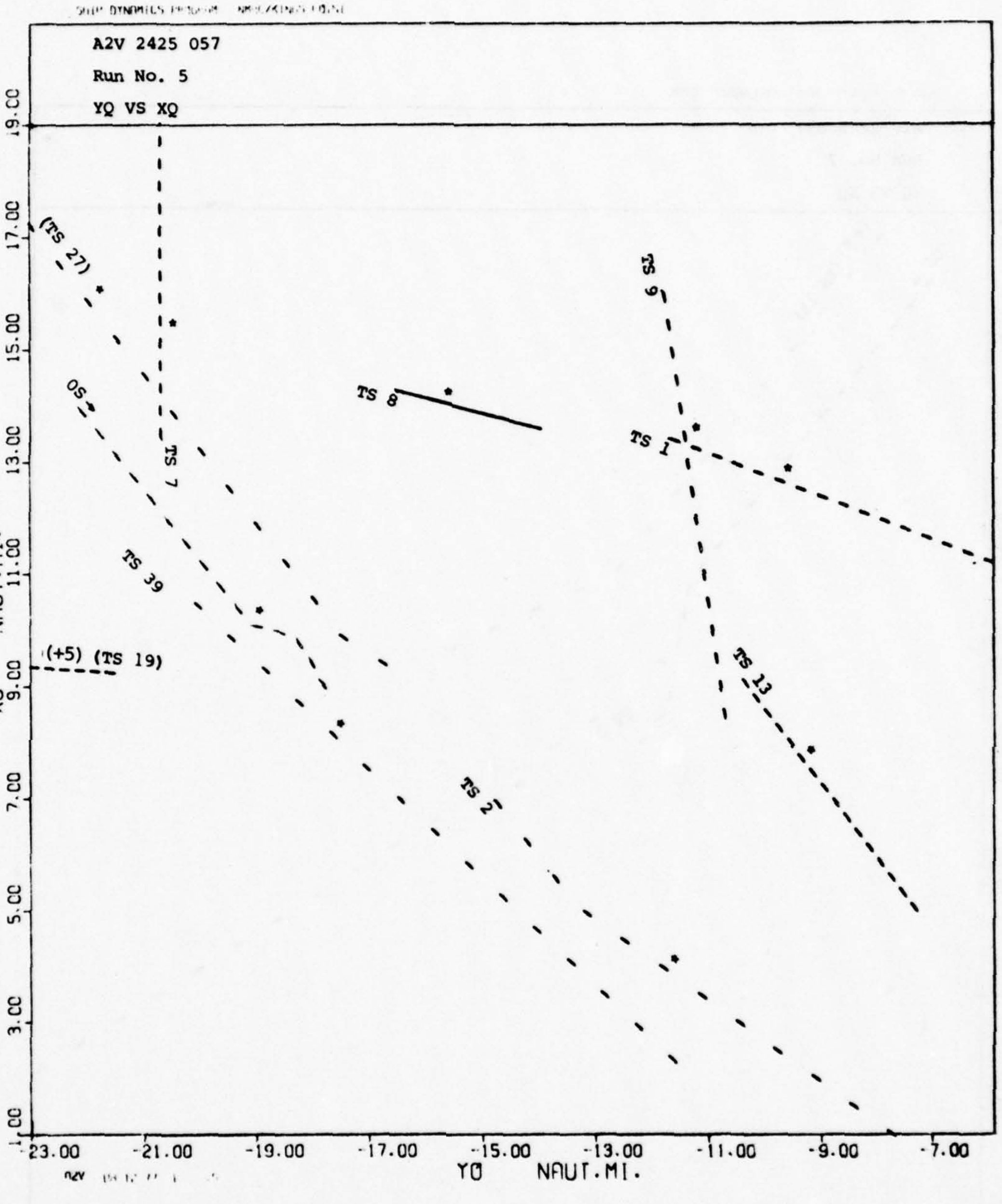

B2V 2422 056
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
47.00
45.00
43.00
41.00
39.00
37.00
35.00
33.00
31.00
29.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
(TS 39)
OS
TS 27


B3V 2422 056
Run No. 4
YO VS XO
XO NAUT.MI.
YO NAUT.MI.
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
44.00
46.00
48.00
50.00
52.00
54.00
56.00
58.00
60.00
62.00
TS 20
TS 25
(TS 14)
OS
(TS 40)
TS 5
TS 26
(+2)
(TS 31)
TS 7

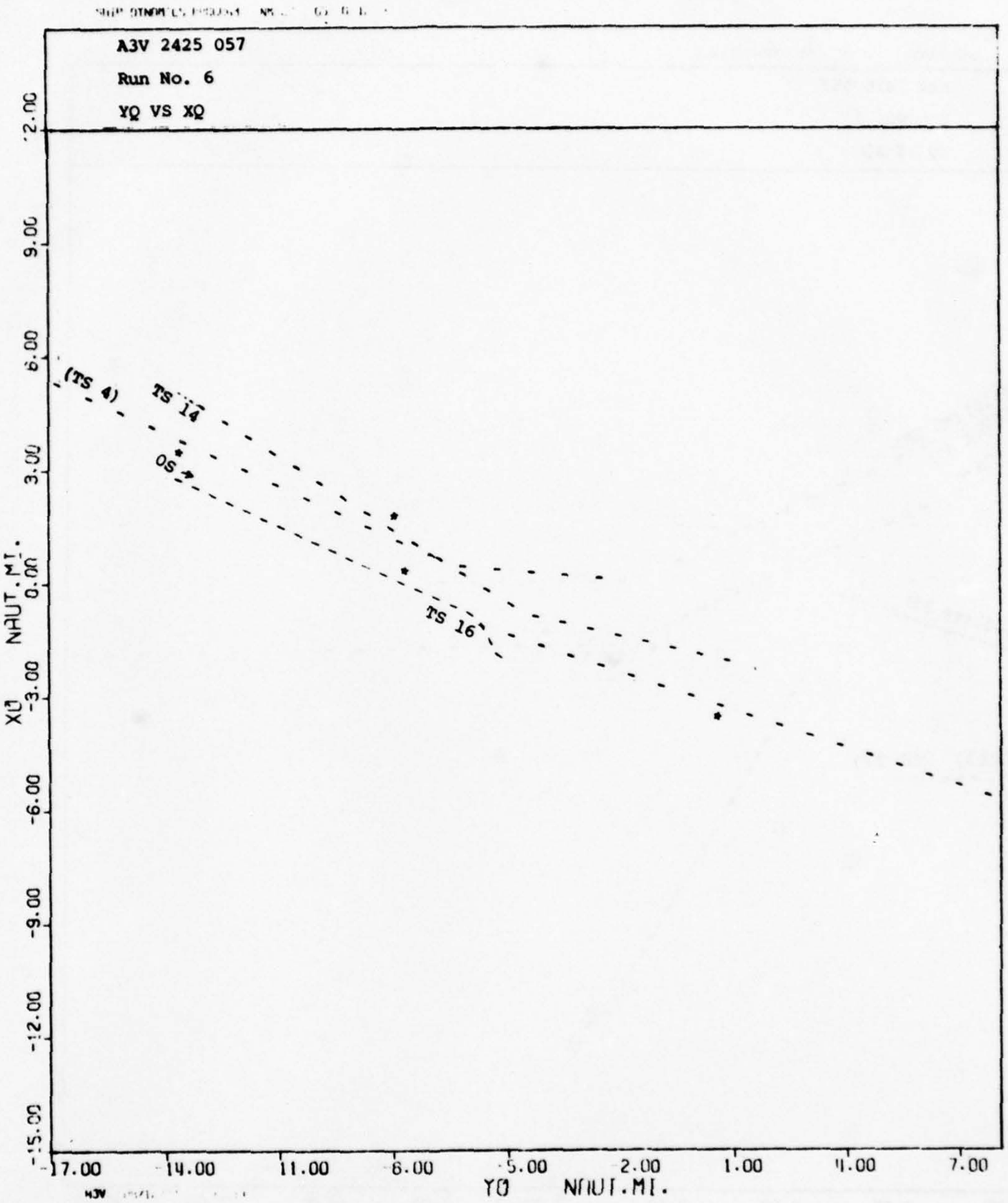

B4V 2423 056
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
TS 17
TS 38
TS 6
(+5)
68.00
66.00
64.00
62.00
60.00
58.00
56.00
54.00
52.00
16.50
18.50
20.50
22.50
26.50
28.50
30.50
32.50

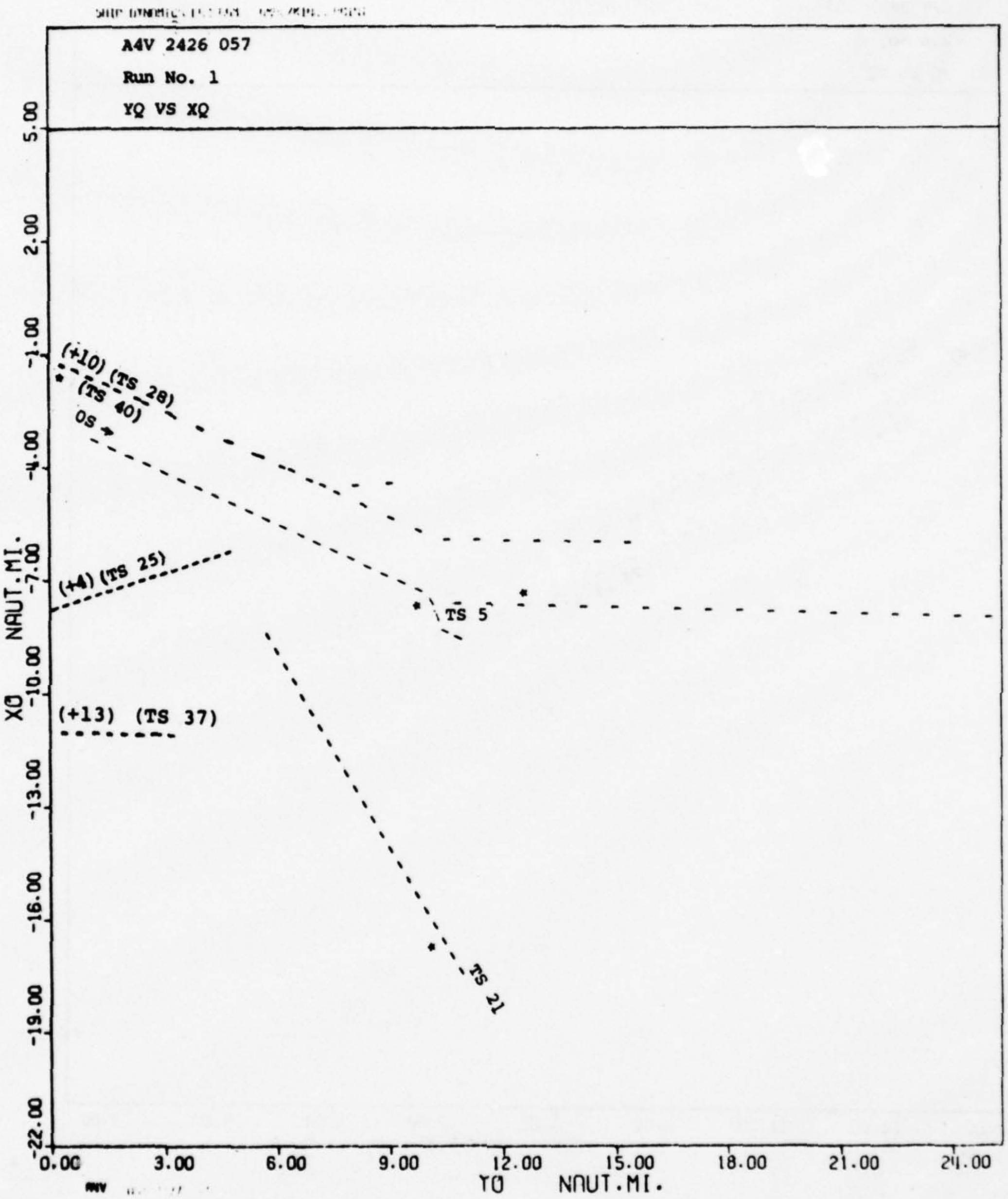


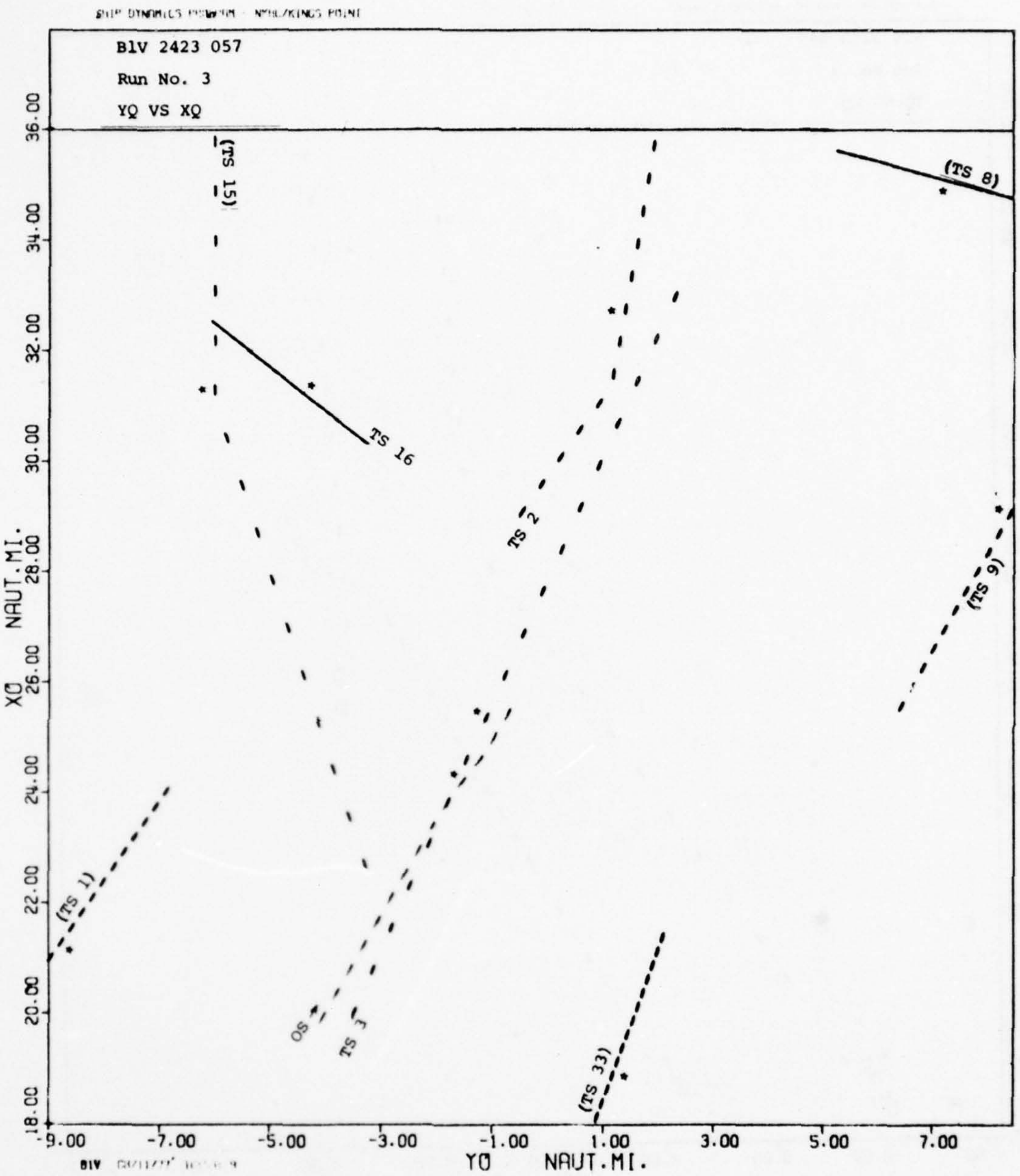
SHIP DYNAMICS PROGRAM
A1V 2425 057
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
(+4)(TS 15)
TS 3
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
-15.00



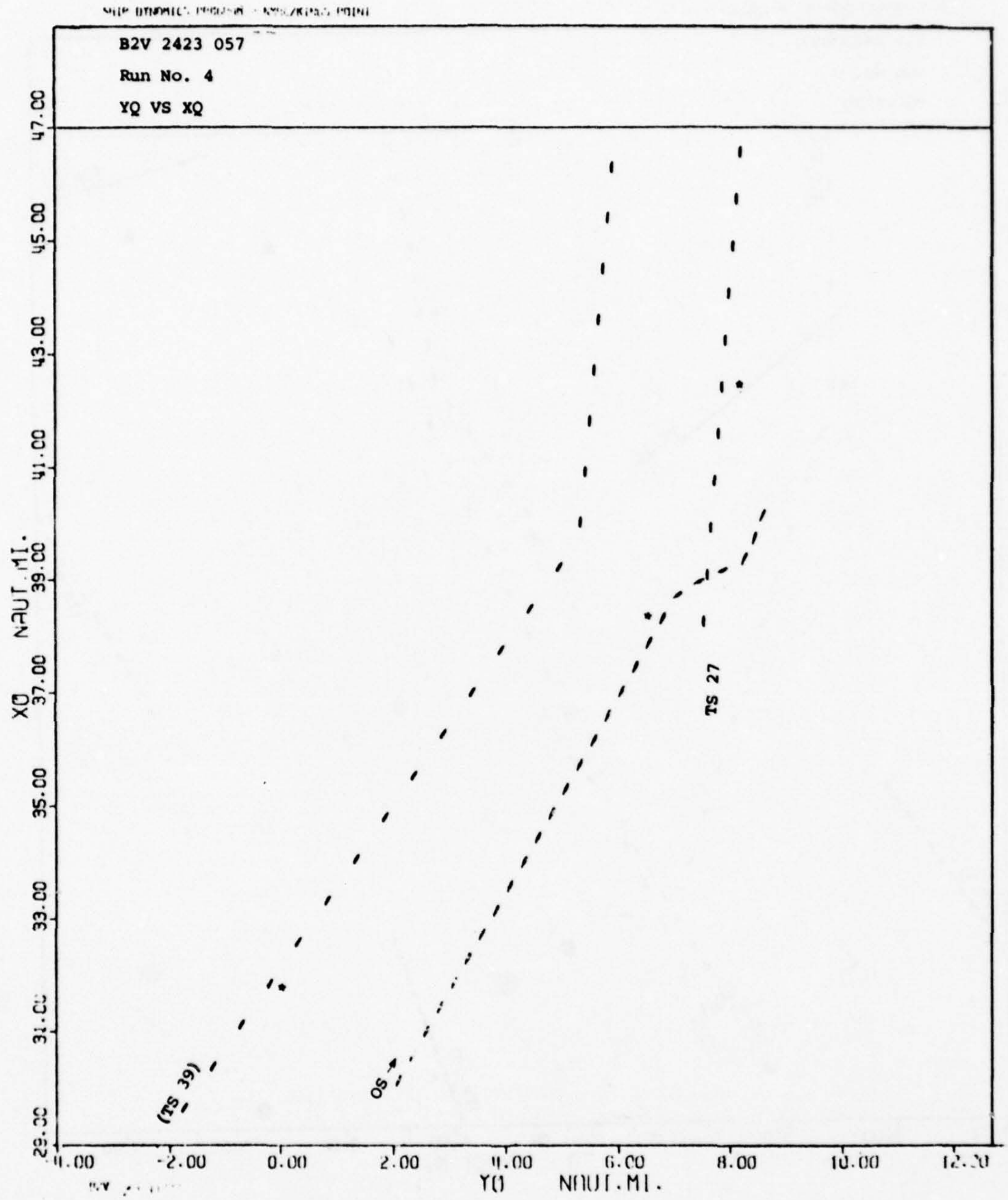
A2V 2425 057
Run No. 5
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-23.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
(TS 27)
TS 7
OS
TS 8
TS 9
TS 1
TS 39
(+5) (TS 19)
TS 13
TS 2

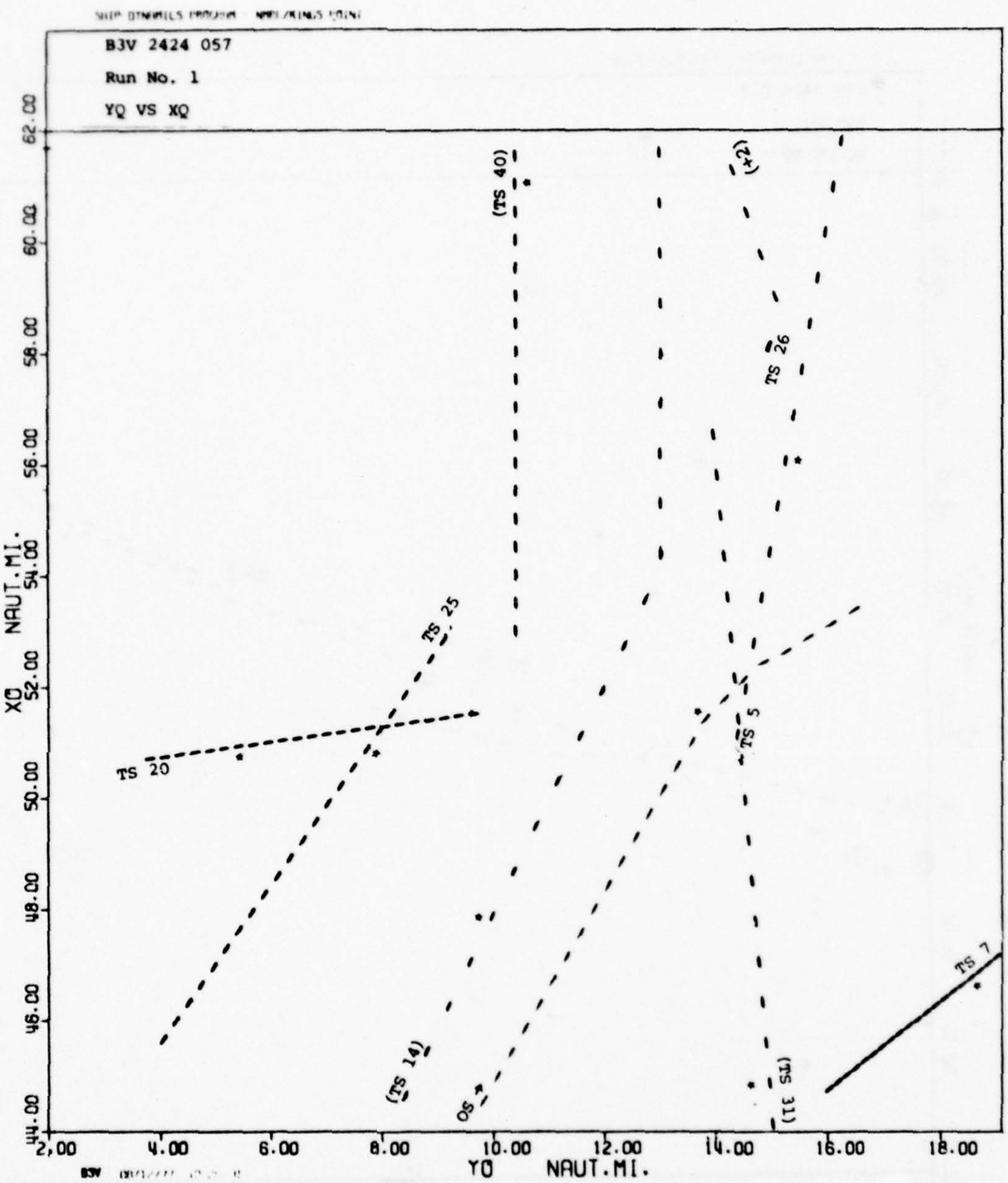

A3V 2425 057
Run No. 6
YQ VS XQ
(TS 4)
TS 14
OS
TS 16
XQ NAUT.MI.
YQ NAUT.MI.
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-17.00
-14.00
-11.00
-8.00
-5.00
-2.00
1.00
4.00
7.00


A4V 2426 057
Run No. 1
YQ VS XQ
(+10) (TS 28)
(TS 40)
OS
(+4) (TS 25)
TS 5
(+13) (TS 37)
TS 21
XO NAUT.MI.
YO NAUT.MI.
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00

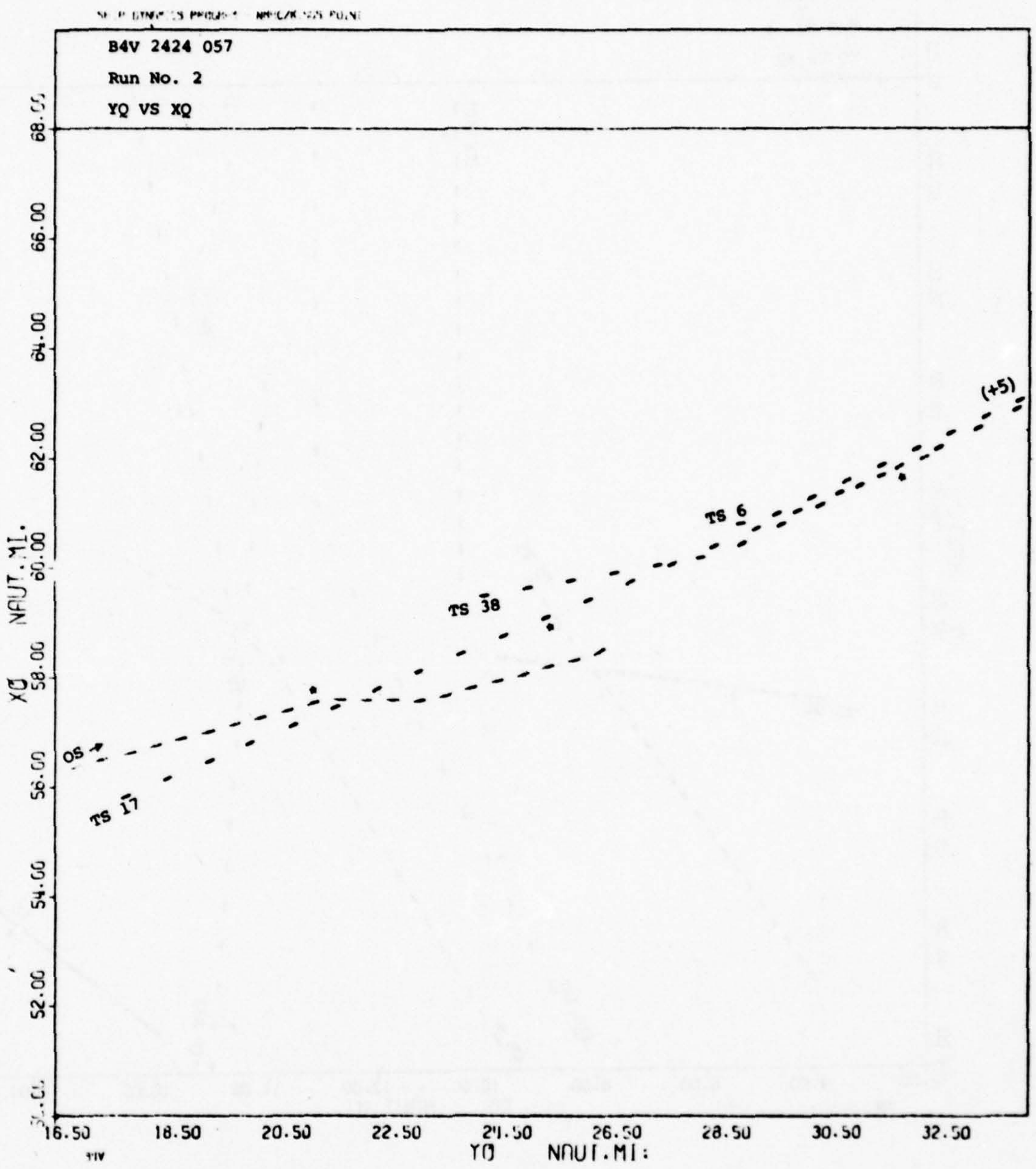


B1V 2423 057
Run No. 3
YQ VS XQ
XO NAUT.MI.
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
-9.00
-7.00
-5.00
-3.00
-1.00
1.00
3.00
5.00
7.00
YO NAUT.MI.
(TS 15)
TS 16
(TS 8)
TS 2
(TS 9)
(TS 1)
OS
TS 3
(TS 33)

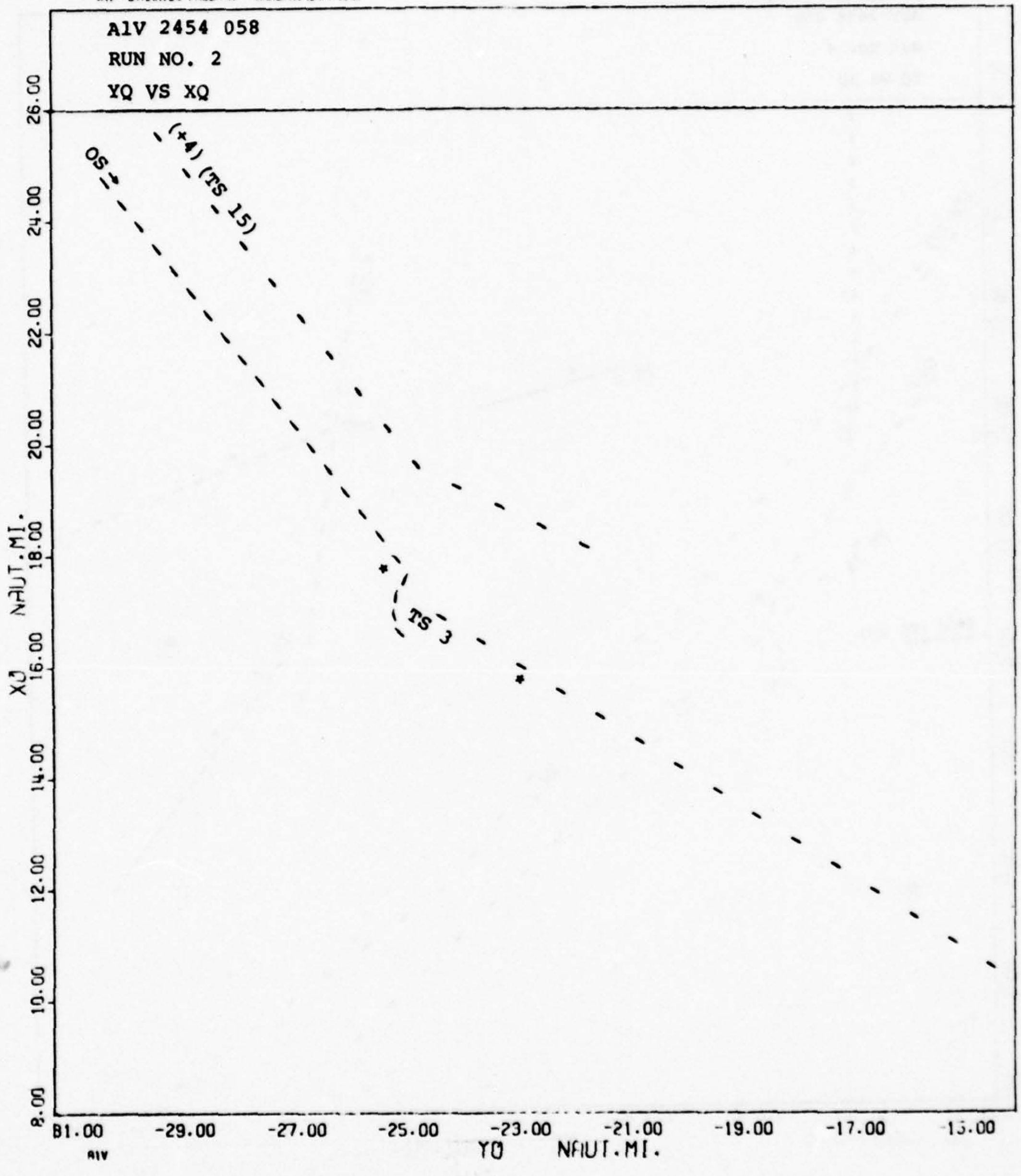

B2V 2423 057
Run No. 4
YQ VS XQ
XQ NAUT.MI.
29.00
31.00
33.00
35.00
37.00
39.00
41.00
43.00
45.00
47.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
YQ NAUT.MI.
(TS 39)
OS
TS 27

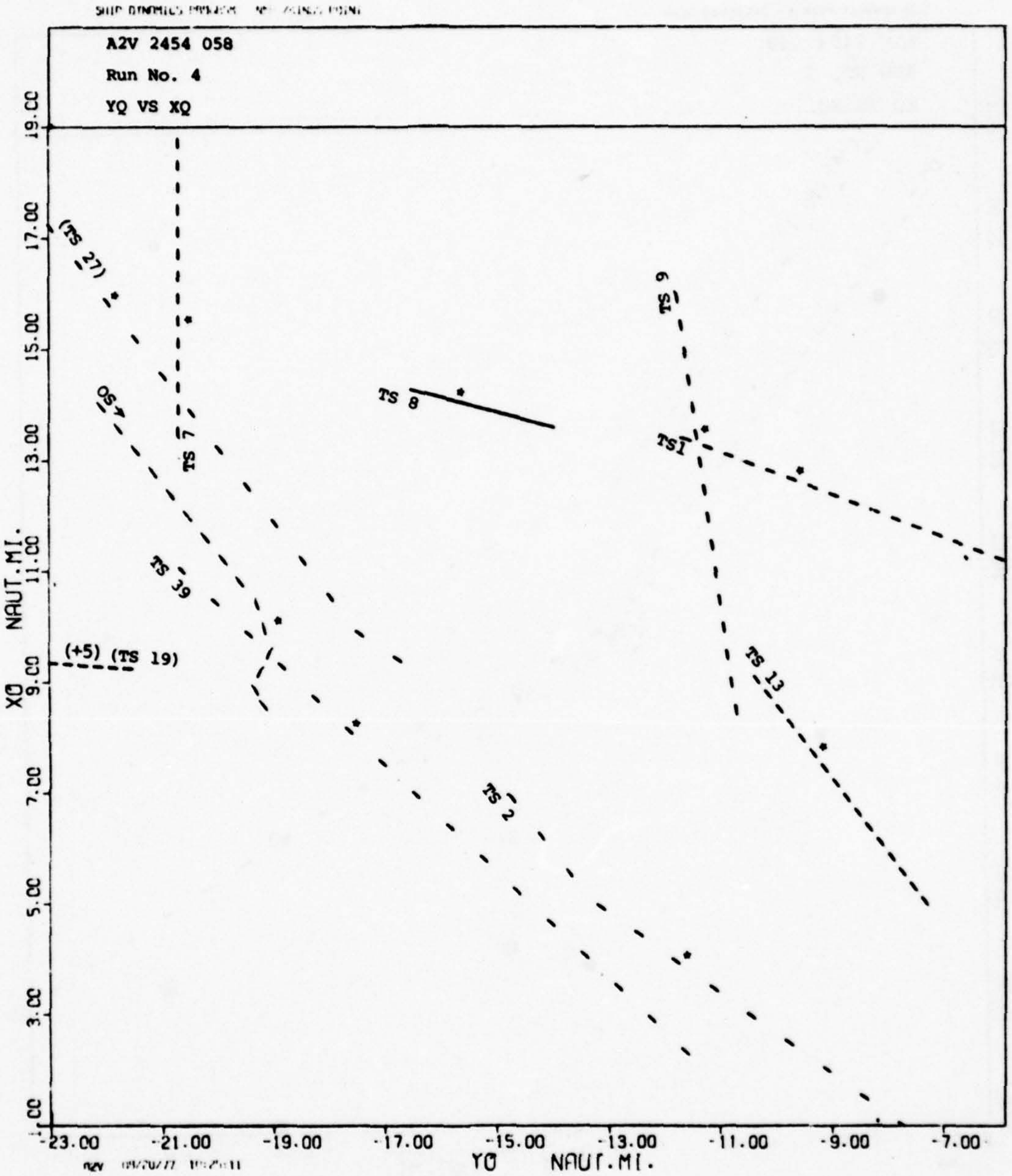


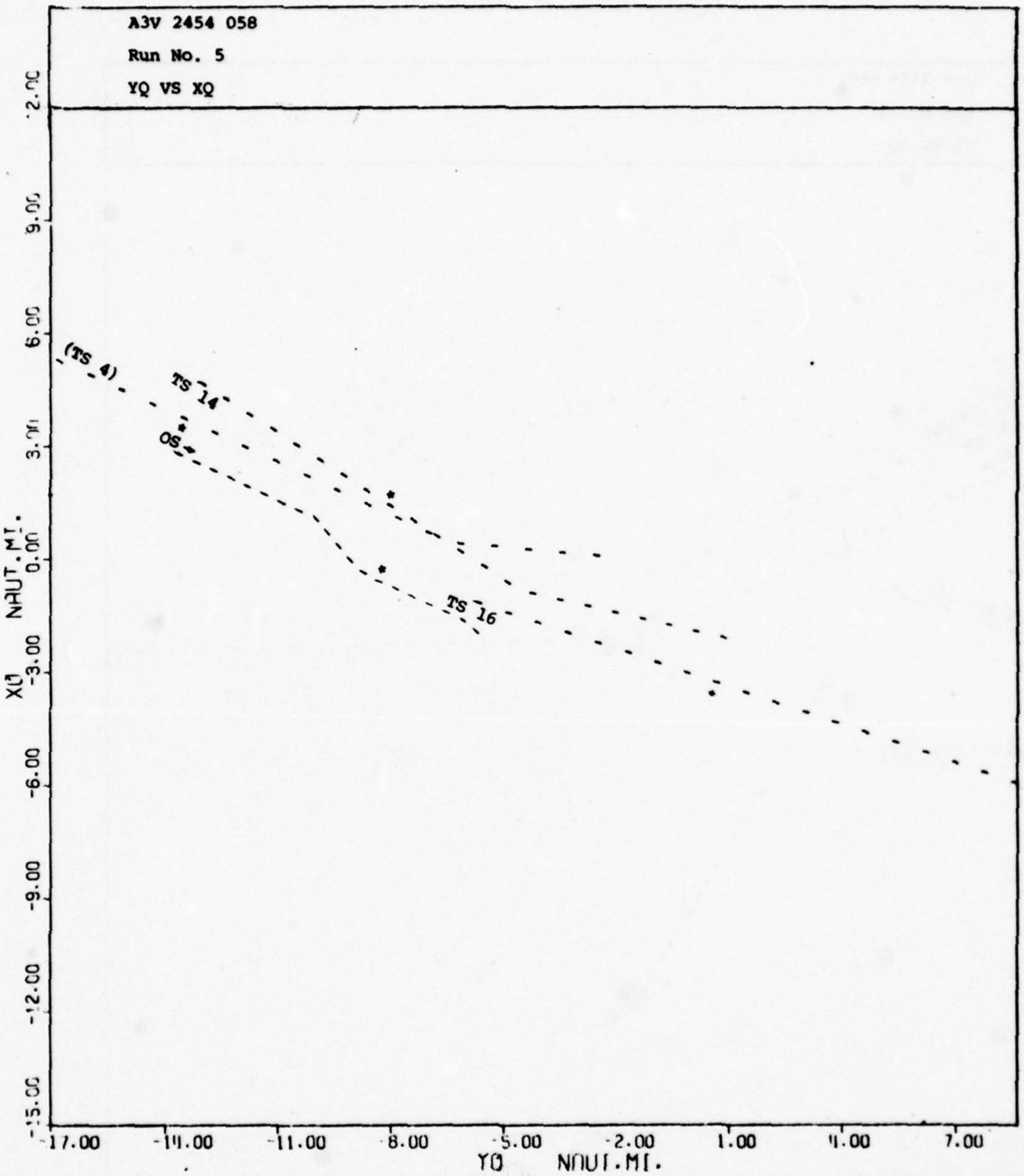
SHIP DYNAMICS PROGRAM - NMRI/KINGS POINT
B3V 2424 057
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
62.00
60.00
58.00
56.00
54.00
52.00
50.00
48.00
46.00
44.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
(TS 40)
(+2)
TS 26
TS 25
TS 20
TS 5
(TS 14)
OS
(TS 31)
TS 7



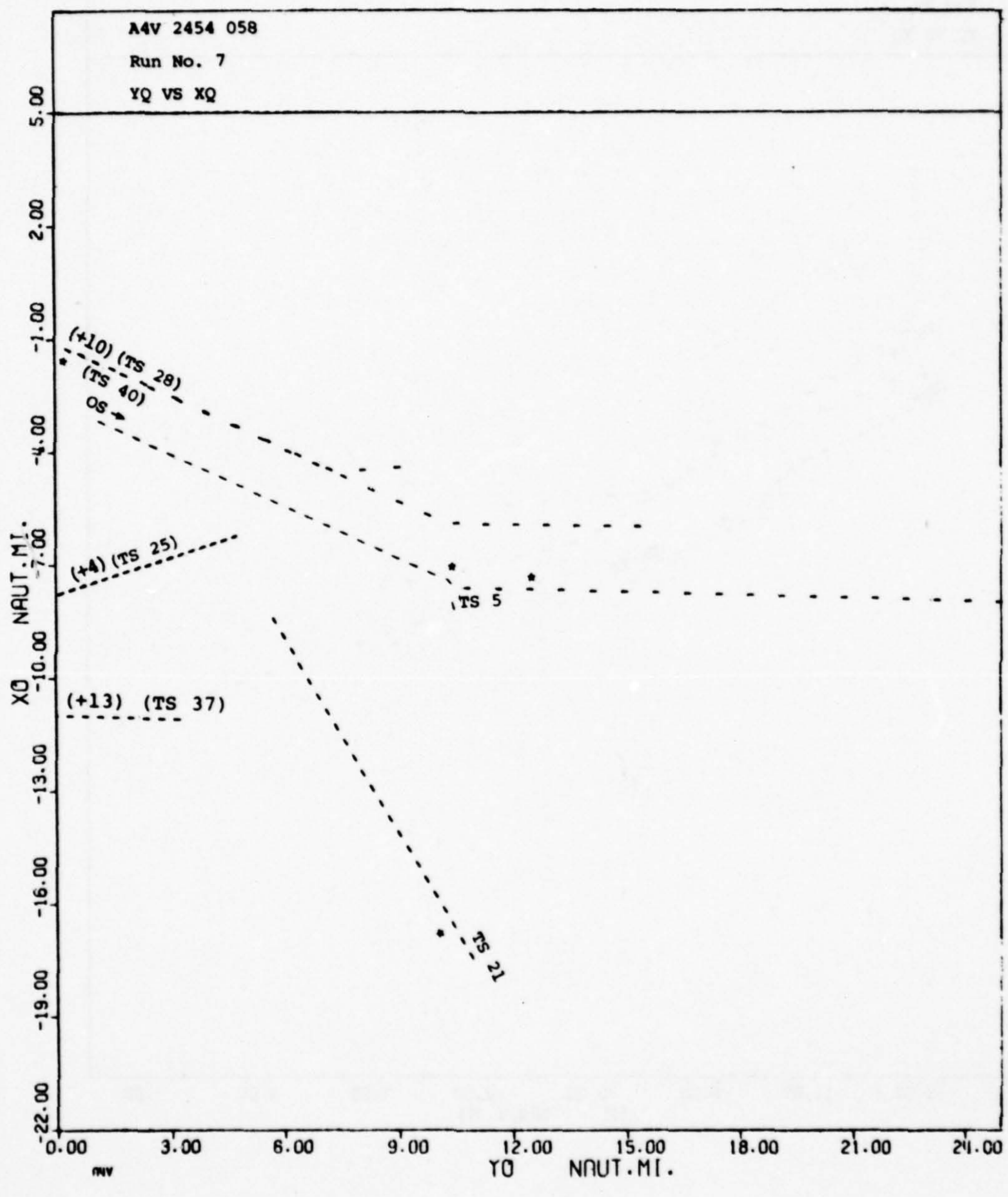
B4V 2424 057
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
TS 17
TS 38
TS 6
(+5)
16.50
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
52.00
54.00
56.00
58.00
60.00
62.00
64.00
66.00
68.00

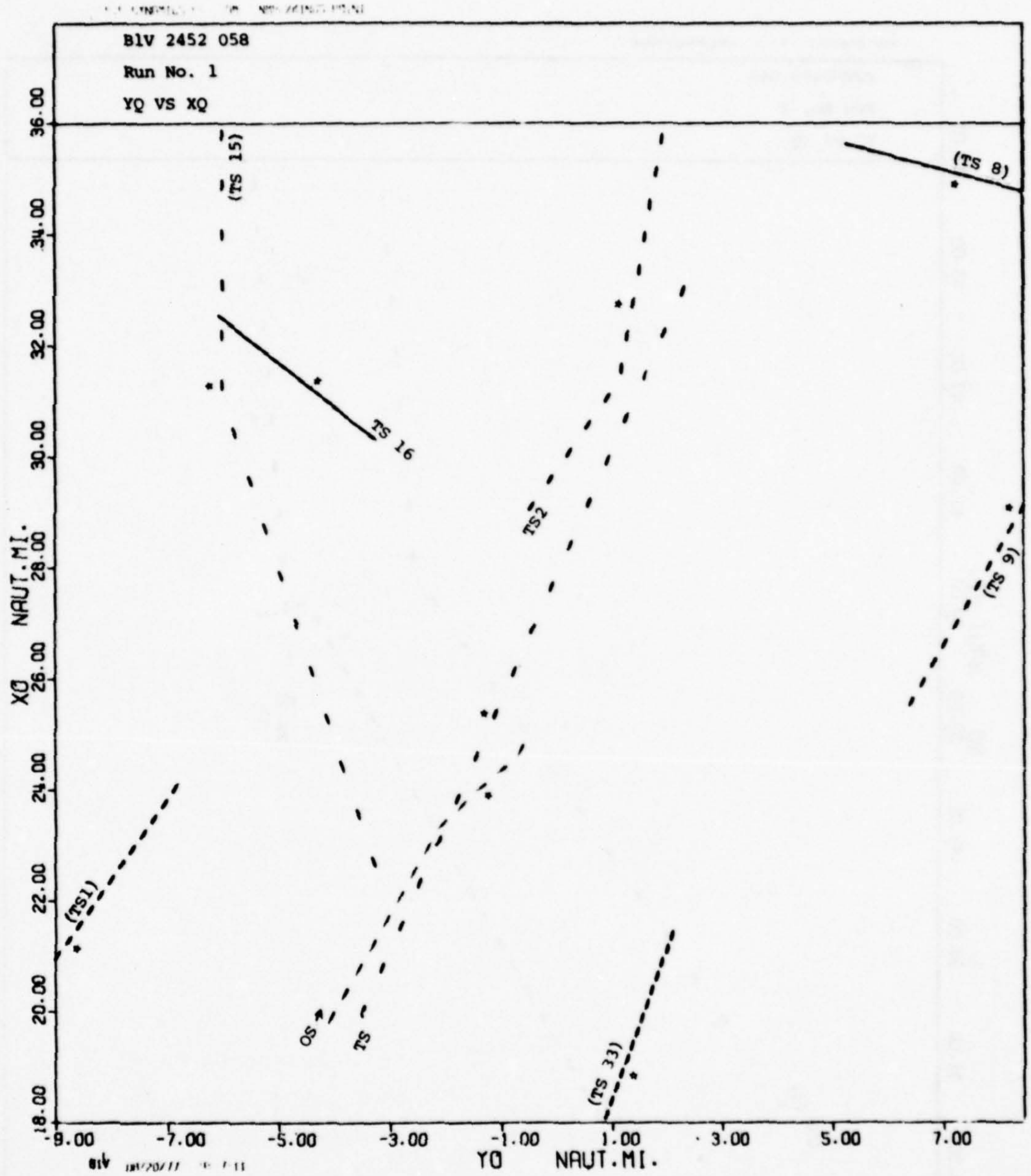

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A1V 2454 058
RUN NO. 2
YQ VS XQ
OS
(+4)
(TS 15)
TS 3
XQ NAUT.MI.
YQ NAUT.MI.
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
-15.00

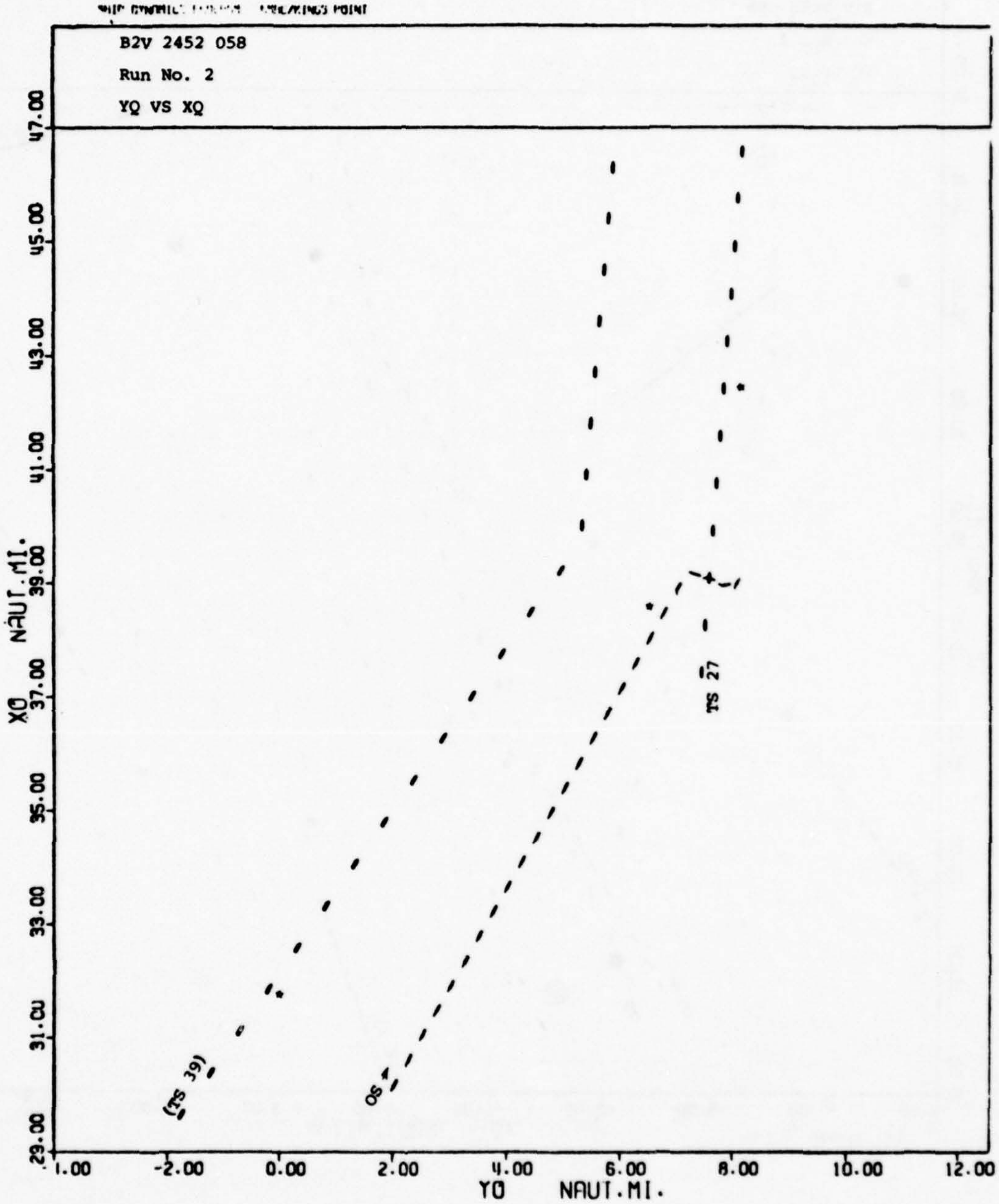

A2V 2454 058
Run No. 4
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
-23.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
(TS 27)
TS 7
TS 8
TS 9
TS1
OS
TS 39
(+5) (TS 19)
TS 13
TS 2

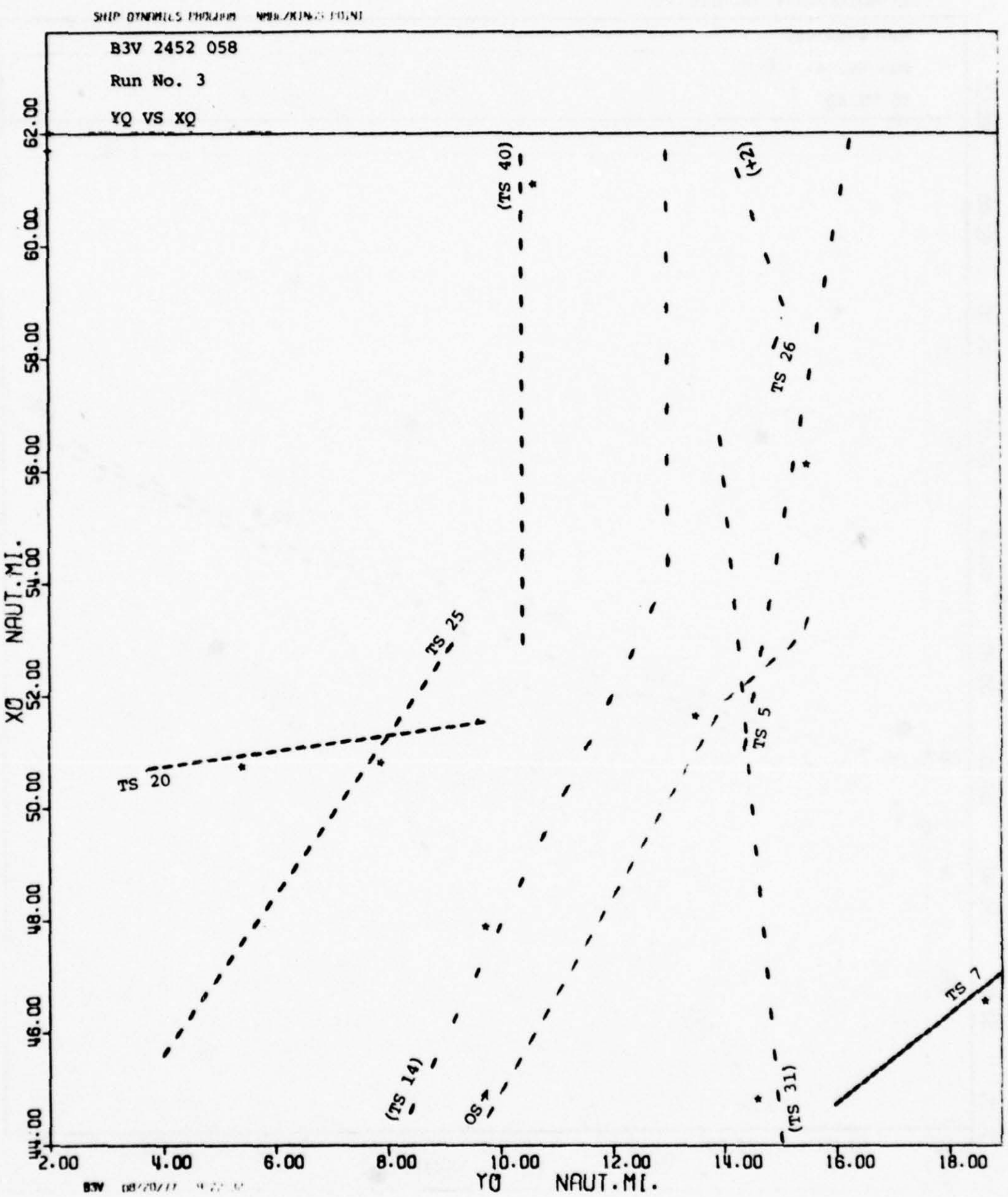


A3V 2454 058
Run No. 5
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
(TS 4)
TS 14
OS
TS 16

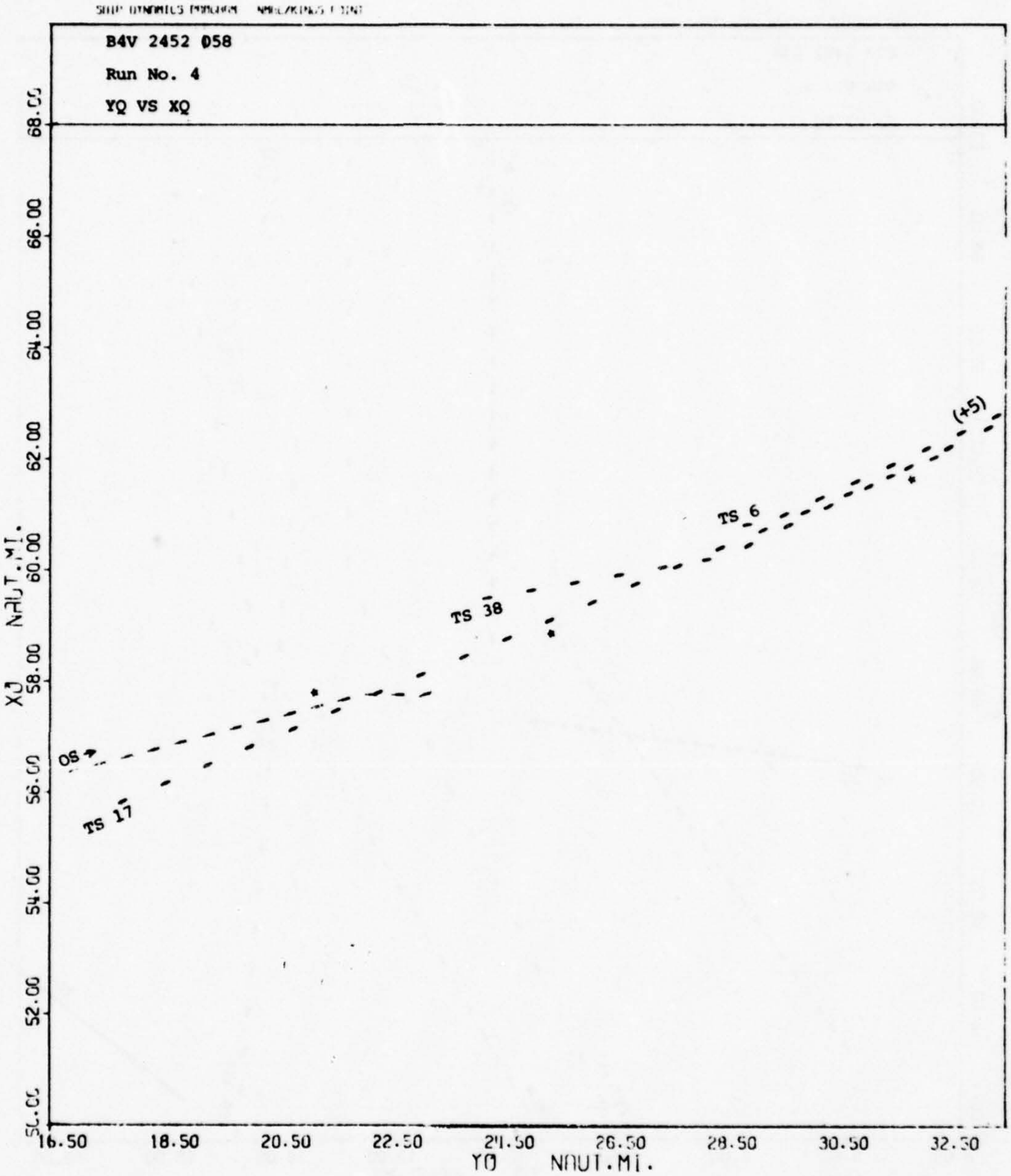

A4V 2454 058
Run No. 7
YQ VS XQ
(+10) (TS 28)
(TS 40)
OS
(+4) (TS 25)
TS 5
(+13) (TS 37)
TS 21
XQ NAUT.MI.
YQ NAUT.MI.
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00

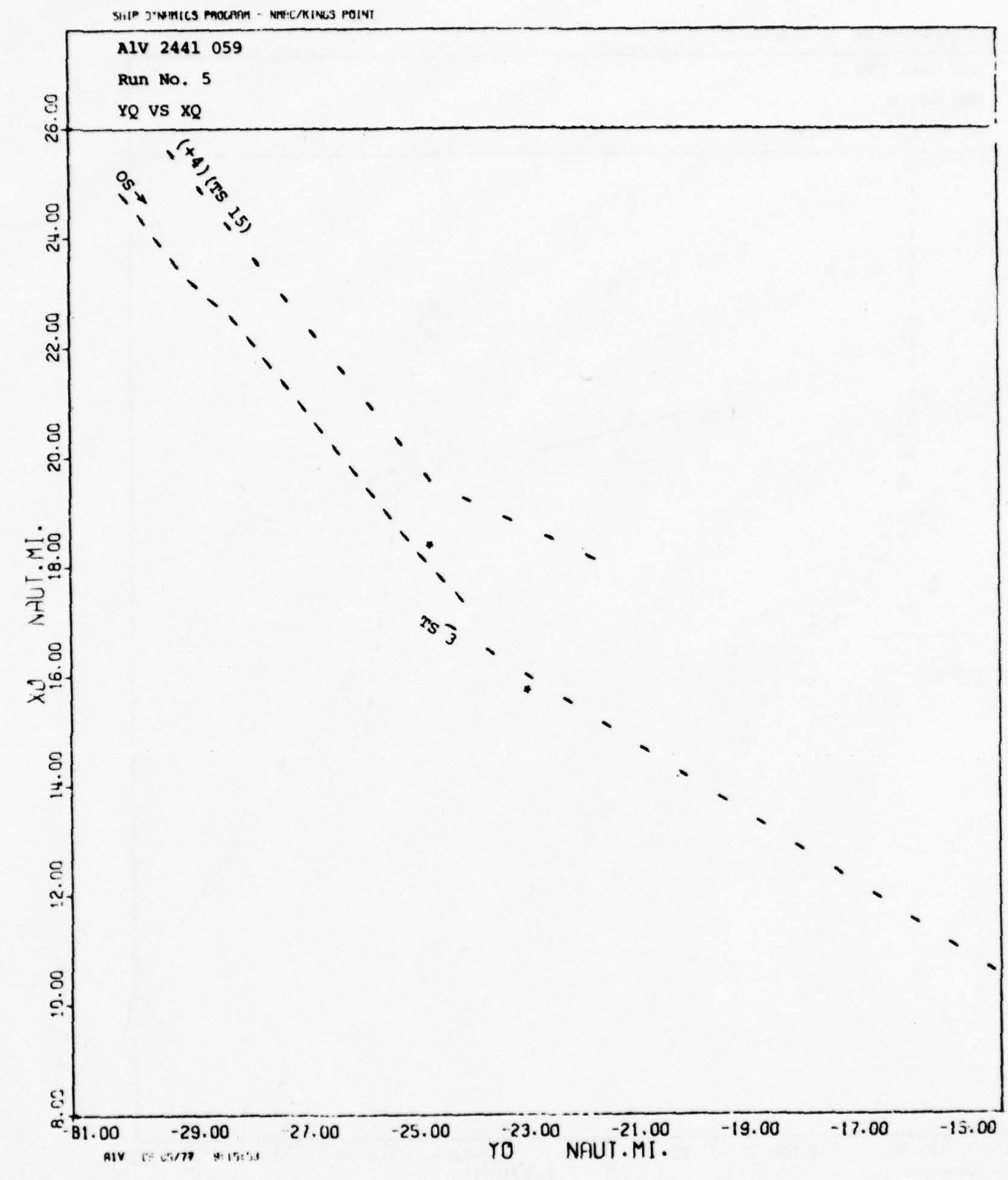

B1V 2452 058
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
-9.00
-7.00
-5.00
-3.00
-1.00
1.00
3.00
5.00
7.00
(TS 15)
TS 16
TS2
(TS 8)
(TS 9)
(TS1)
OS
TS
(TS 33)


B2V 2452 058
Run No. 2
YQ VS XQ
XO NAUT.MI.
YO NAUT.MI.
47.00
45.00
43.00
41.00
39.00
37.00
35.00
33.00
31.00
29.00
1.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
(TS 39)
OS
TS 27

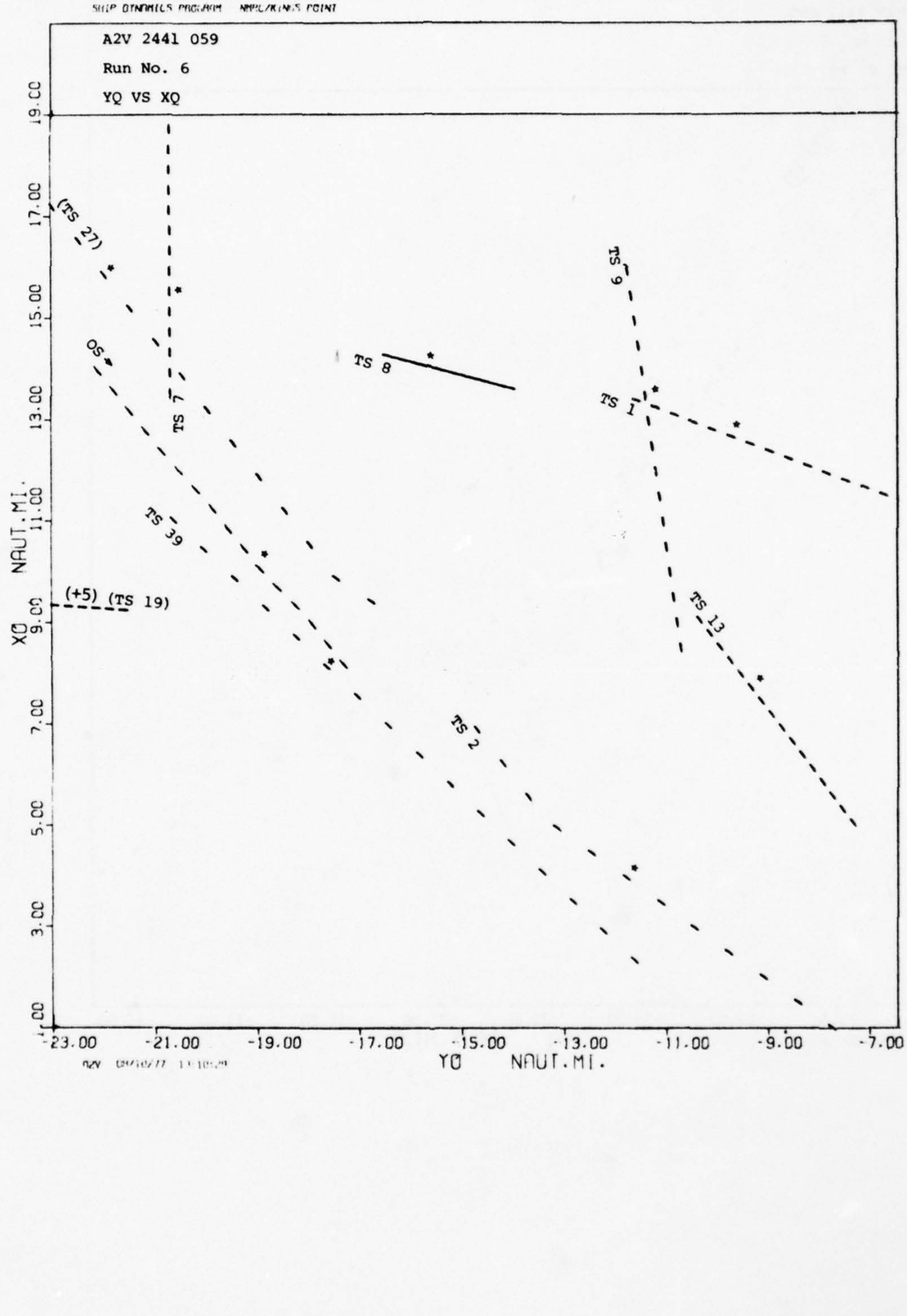


SHIP DYNAMICS PROGRAM
B3V 2452 058
Run No. 3
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
62.00
60.00
58.00
56.00
54.00
52.00
50.00
48.00
46.00
44.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
(TS 40)
(+2)
TS 26
TS 25
TS 20
TS 5
(TS 14)
OS
(TS 31)
TS 7
B3V

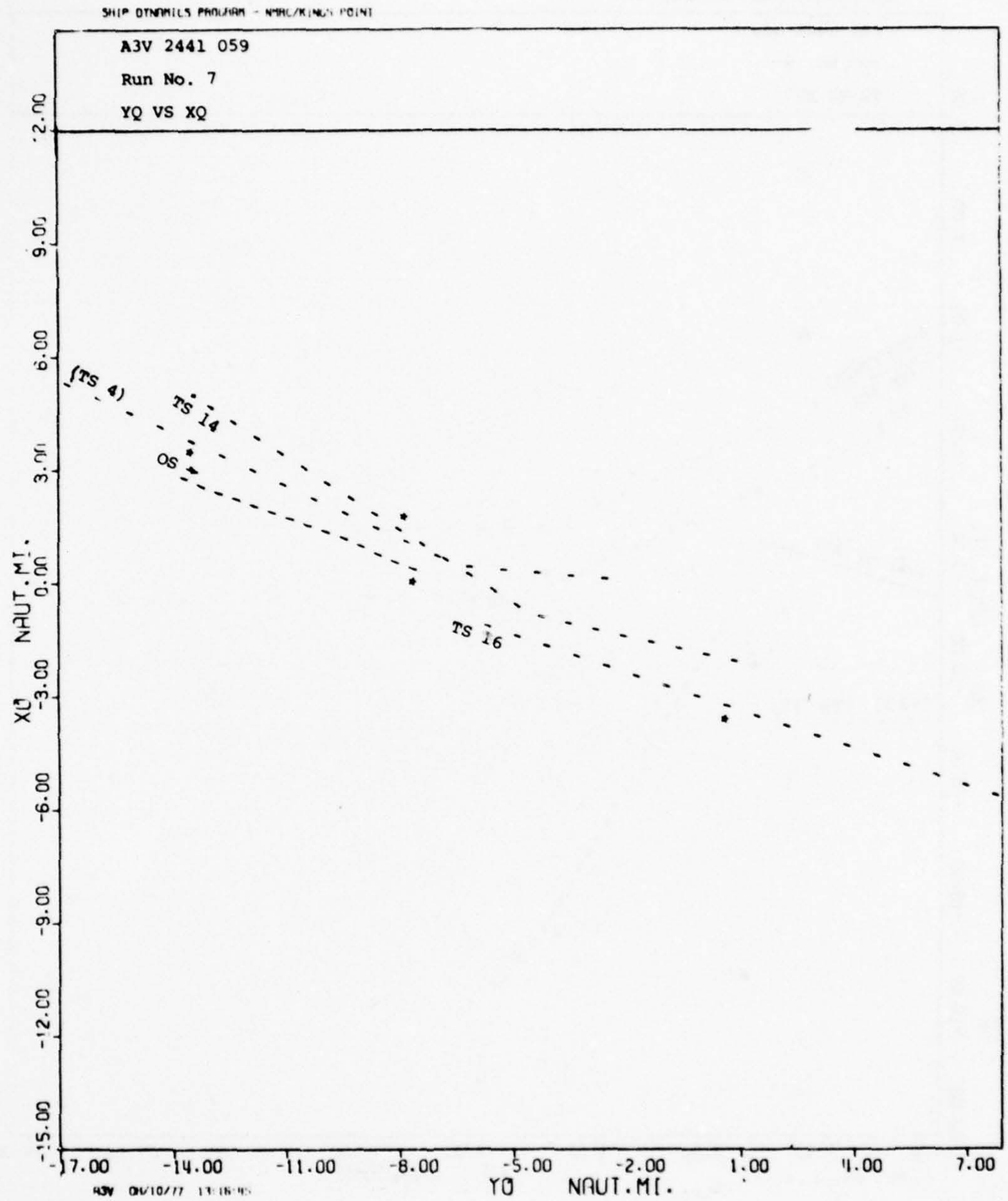

B4V 2452 Ø58
Run No. 4
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
TS 17
TS 38
TS 6
(+5)
16.50
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
50.00
52.00
54.00
56.00
58.00
60.00
62.00
64.00
66.00
68.00

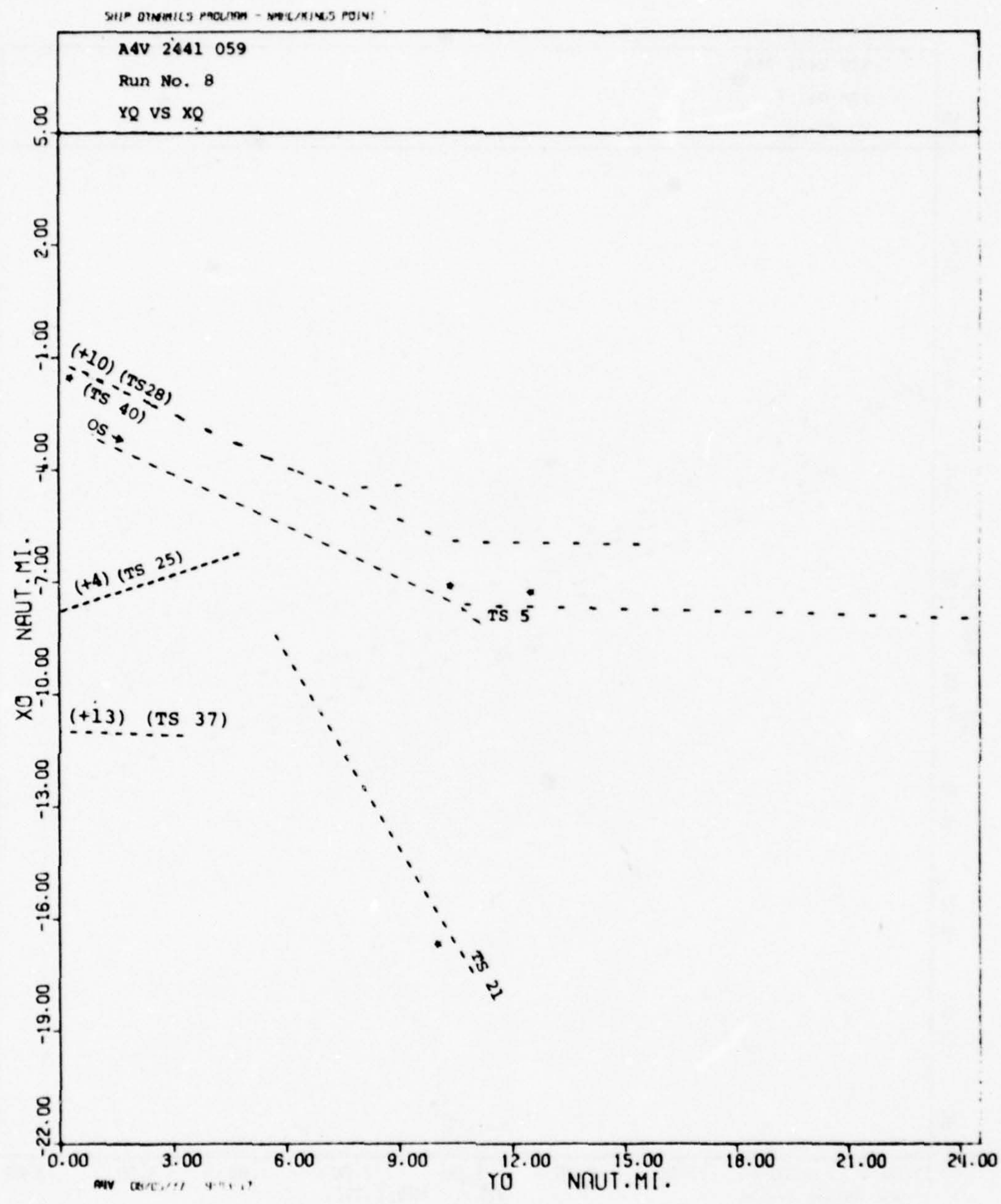


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
AlV 2441 059
Run No. 5
YQ VS XQ
OS
(+4)(TS 15)
TS 3
XQ NAUT.MI.
YQ NAUT.MI.
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
26.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
-15.00

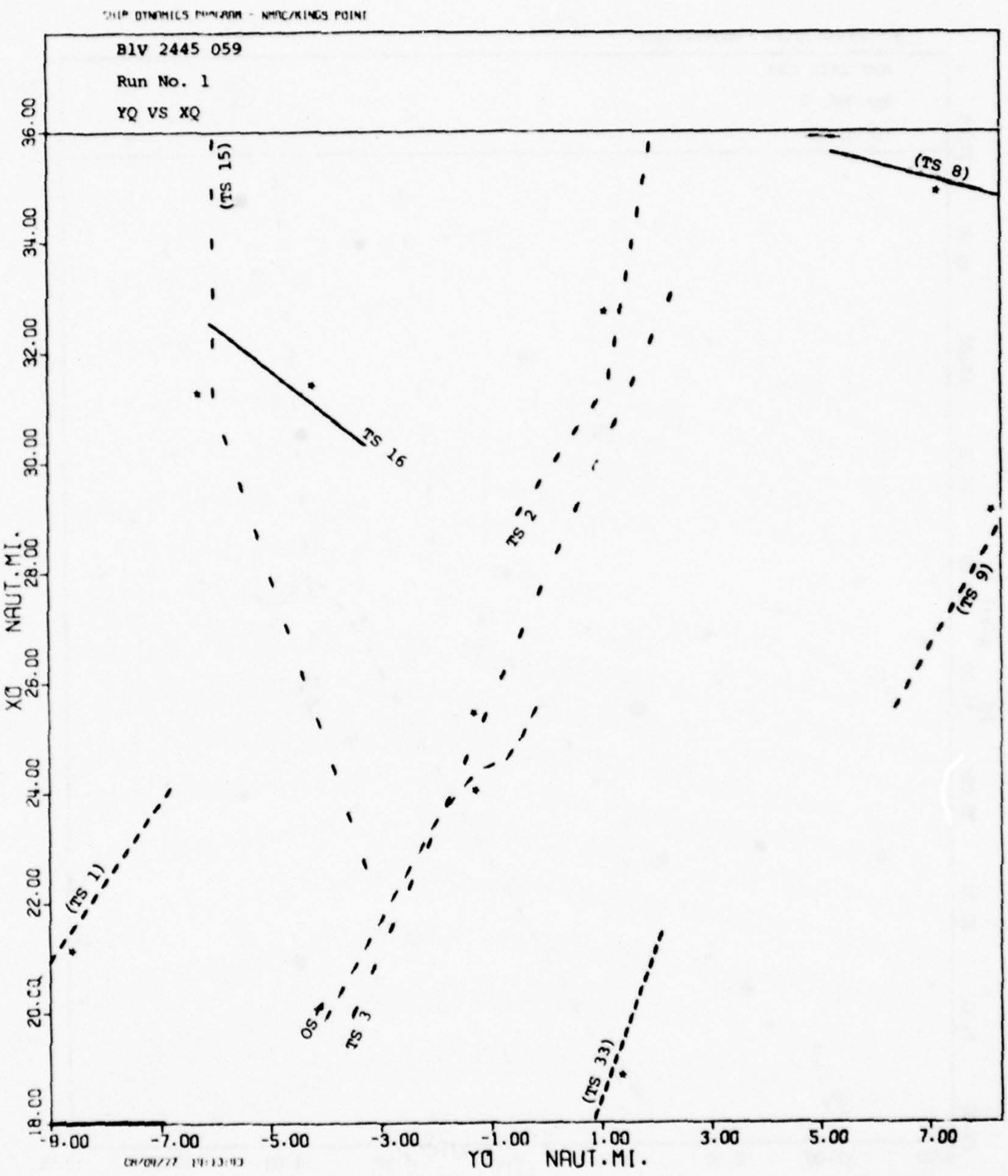


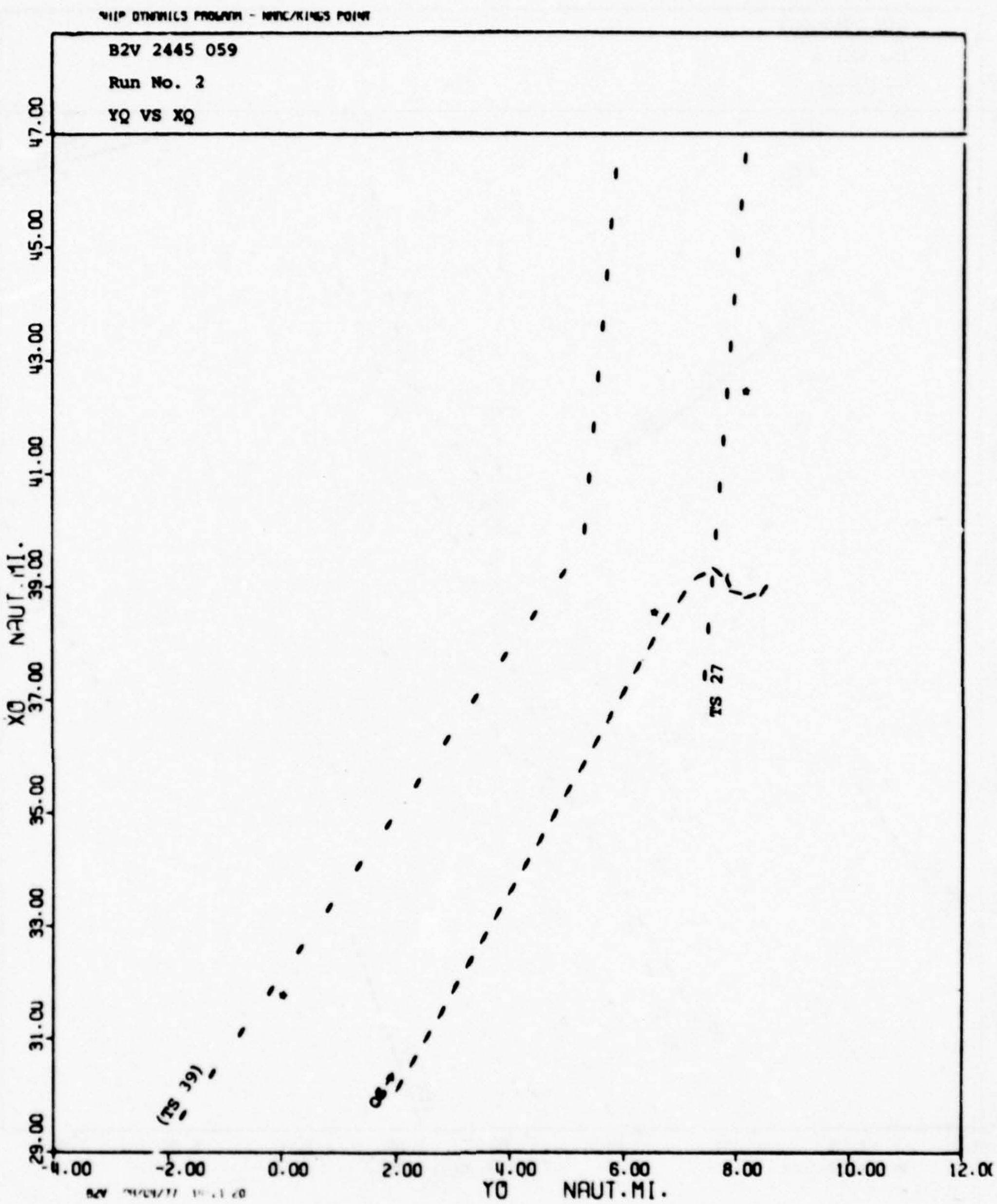
SHIP DYNAMICS PROGRAM NMRL/KINGS POINT
A2V 2441 059
Run No. 6
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-23.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
(TS 27)
TS 7
OS
TS 8
TS 6
TS 1
TS 39
(+5) (TS 19)
TS 13
TS 2


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A3V 2441 059
Run No. 7
YQ VS XQ
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
XQ NAUT.MI.
(TS 4)
TS 14
OS
TS 16
-17.00
-14.00
-11.00
-8.00
-5.00
-2.00
1.00
4.00
7.00
YQ NAUT.MI.

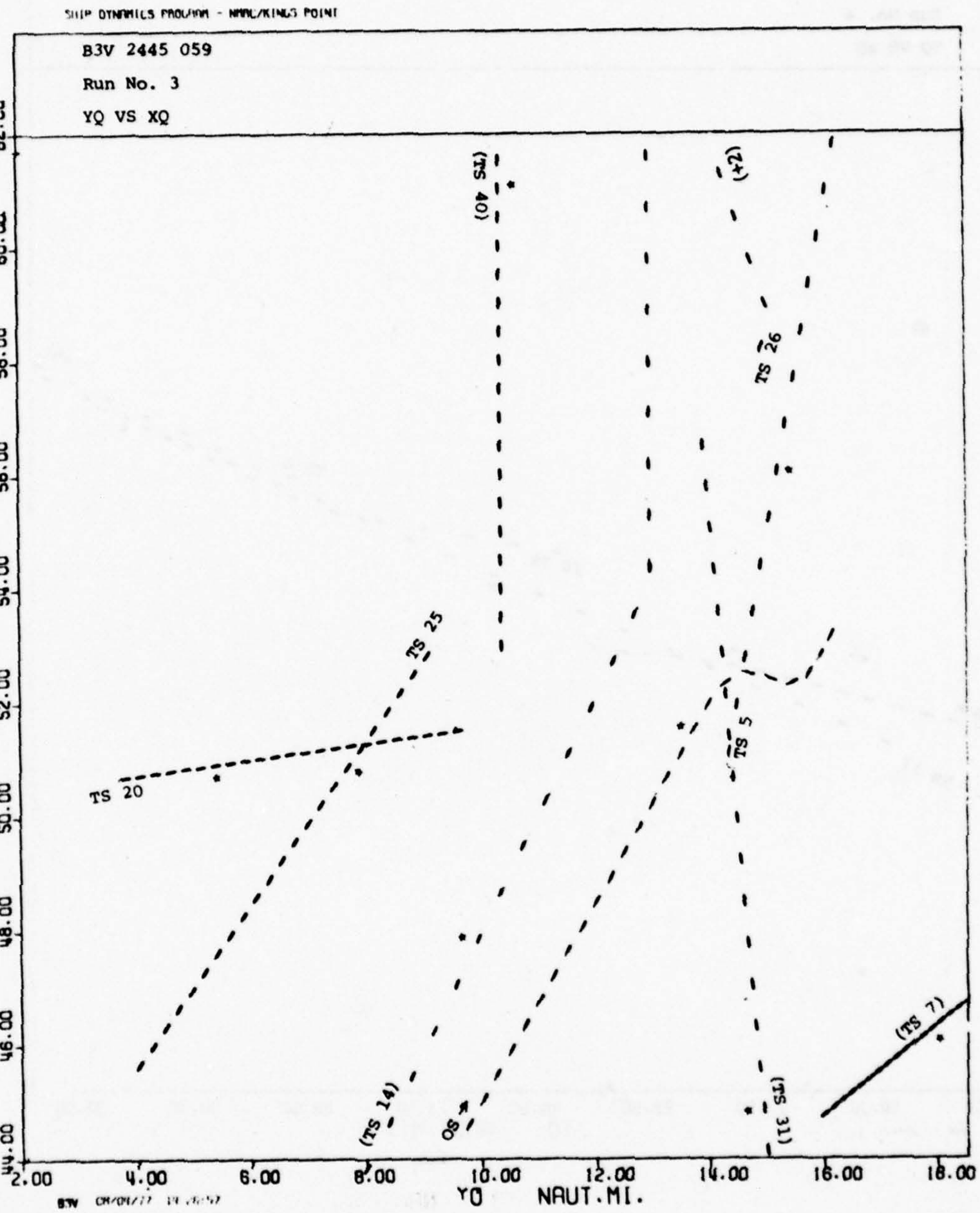


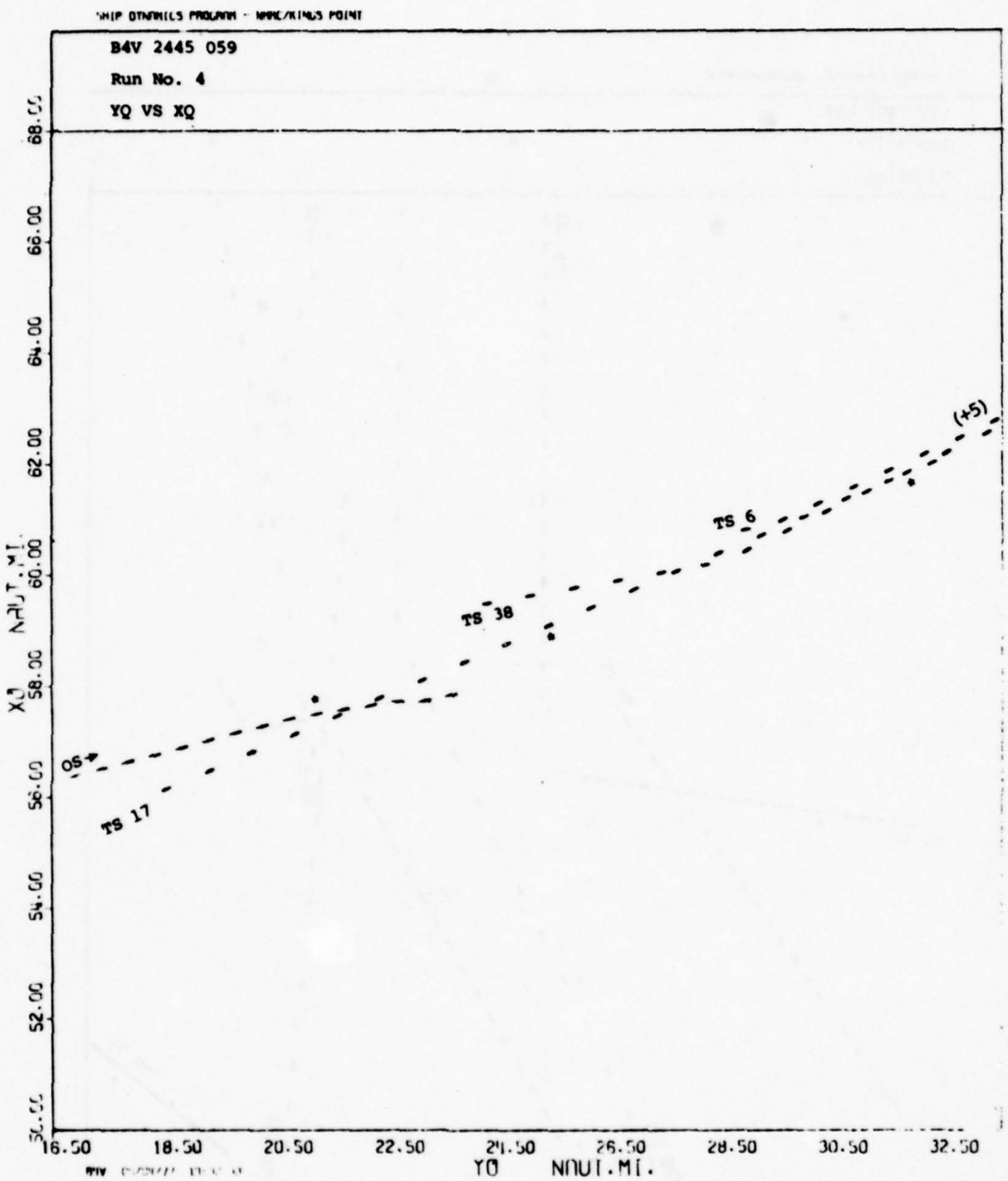
SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A4V 2441 059
Run No. 8
YQ VS XQ
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
XQ NAUT.MI.
(+10) (TS28)
(TS 40)
OS
(+4) (TS 25)
TS 5
(+13) (TS 37)
TS 21
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
YQ NAUT.MI.


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B1V 2445 059
Run No. 1
YQ VS XQ
(TS 15)
TS 16
(TS 8)
TS 2
(TS 9)
(TS 1)
OS
TS 3
(TS 33)
XQ NAUT.MI.
YQ NAUT.MI.
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
-9.00
-7.00
-5.00
-3.00
-1.00
1.00
3.00
5.00
7.00

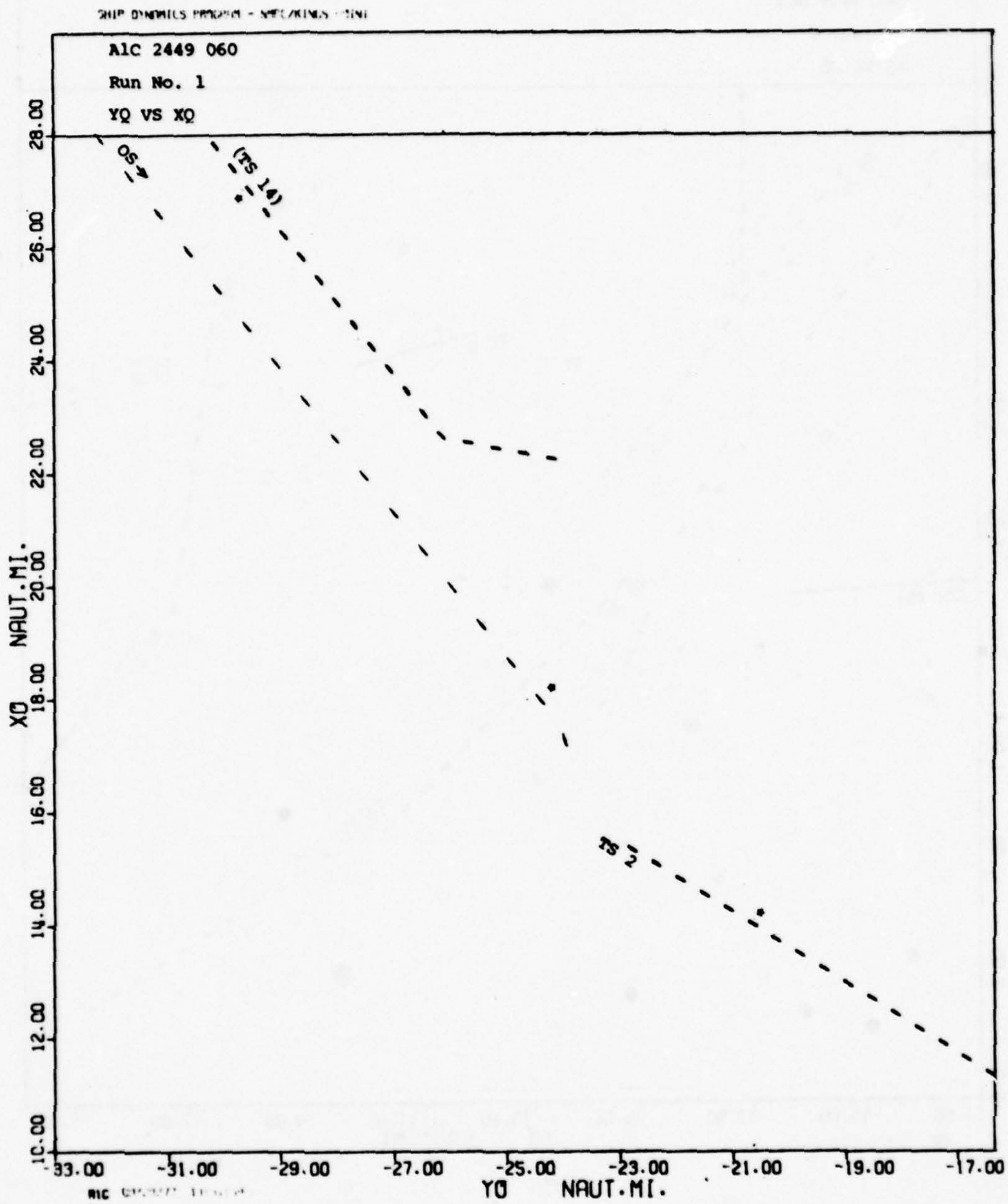


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B2V 2445 059
Run No. 2
YQ VS XQ
47.00
45.00
43.00
41.00
39.00
37.00
35.00
33.00
31.00
29.00
XQ NAUT.MI.
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
YQ NAUT.MI.
(TS 39)
OS
TS 27

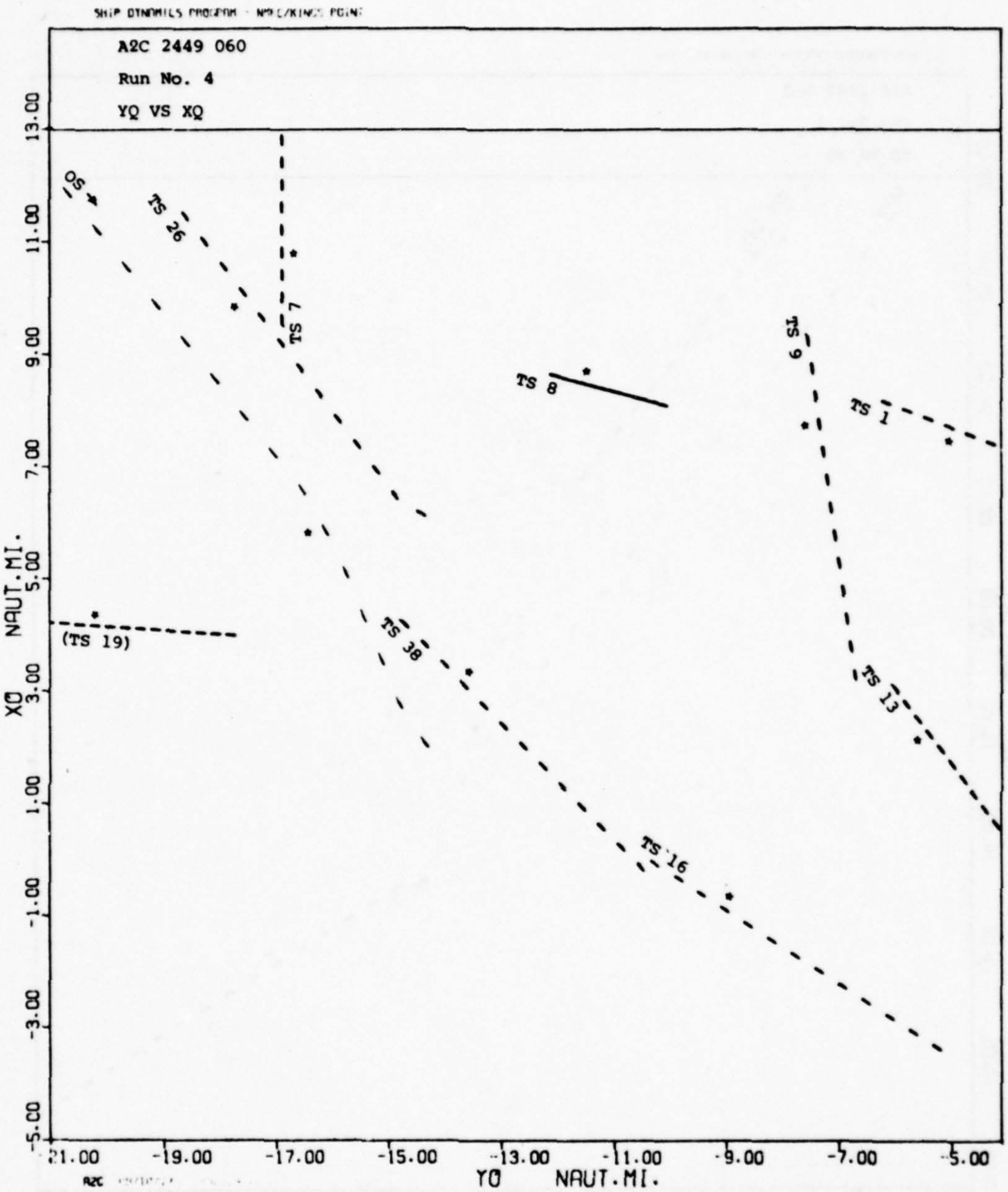

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B3V 2445 059
Run No. 3
YQ VS XQ
XQ NAUT.MI.
YO NAUT.MI.
62.00
60.00
58.00
56.00
54.00
52.00
50.00
48.00
46.00
44.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
(TS 40)
(+2)
TS 26
TS 25
TS 20
TS 5
(TS 7)
(TS 14)
OS
(TS 31)

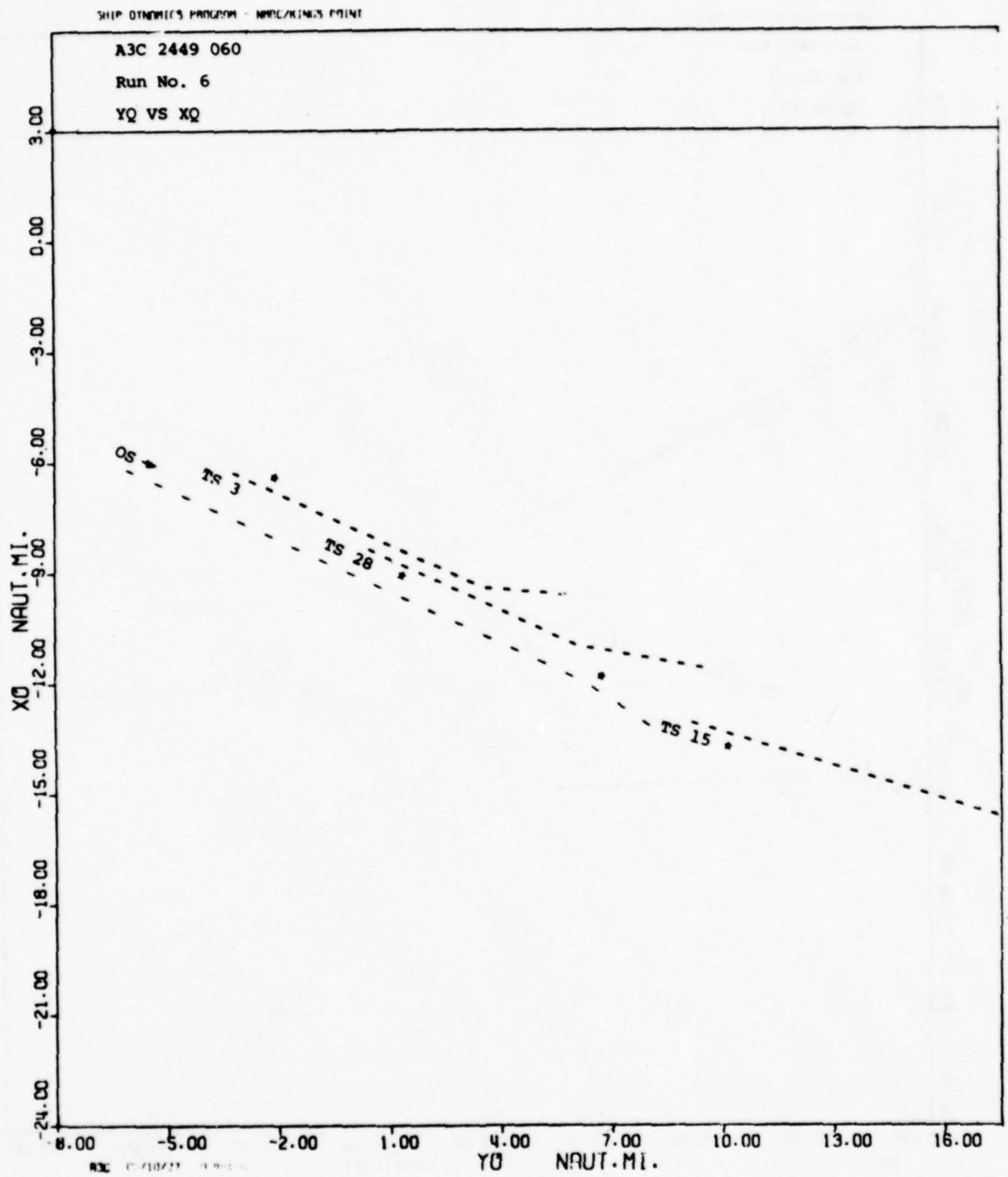


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B4V 2445 059
Run No. 4
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
TS 17
TS 38
TS 6
(+5)
16.50
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
52.00
54.00
56.00
58.00
60.00
62.00
64.00
66.00
68.00

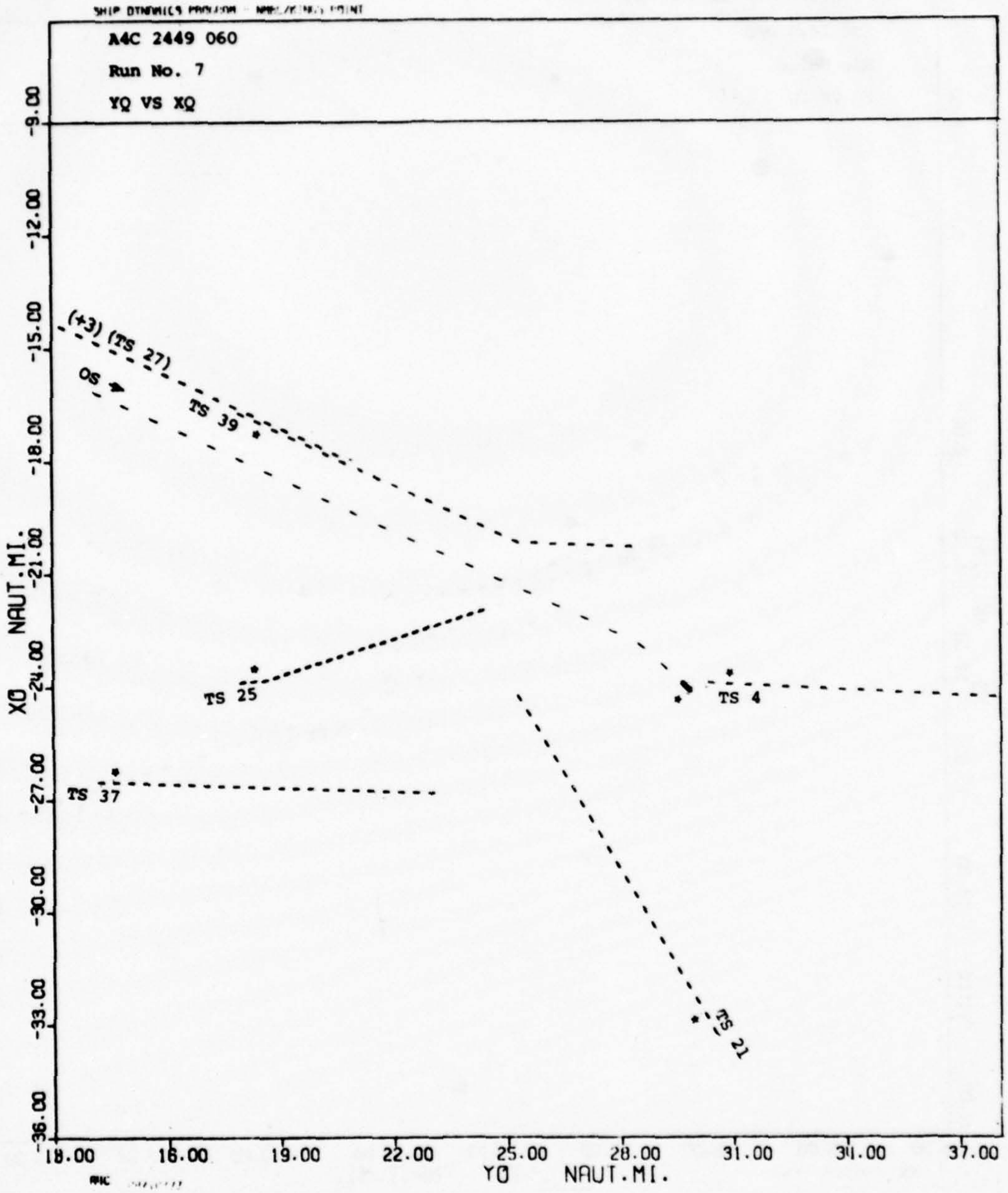


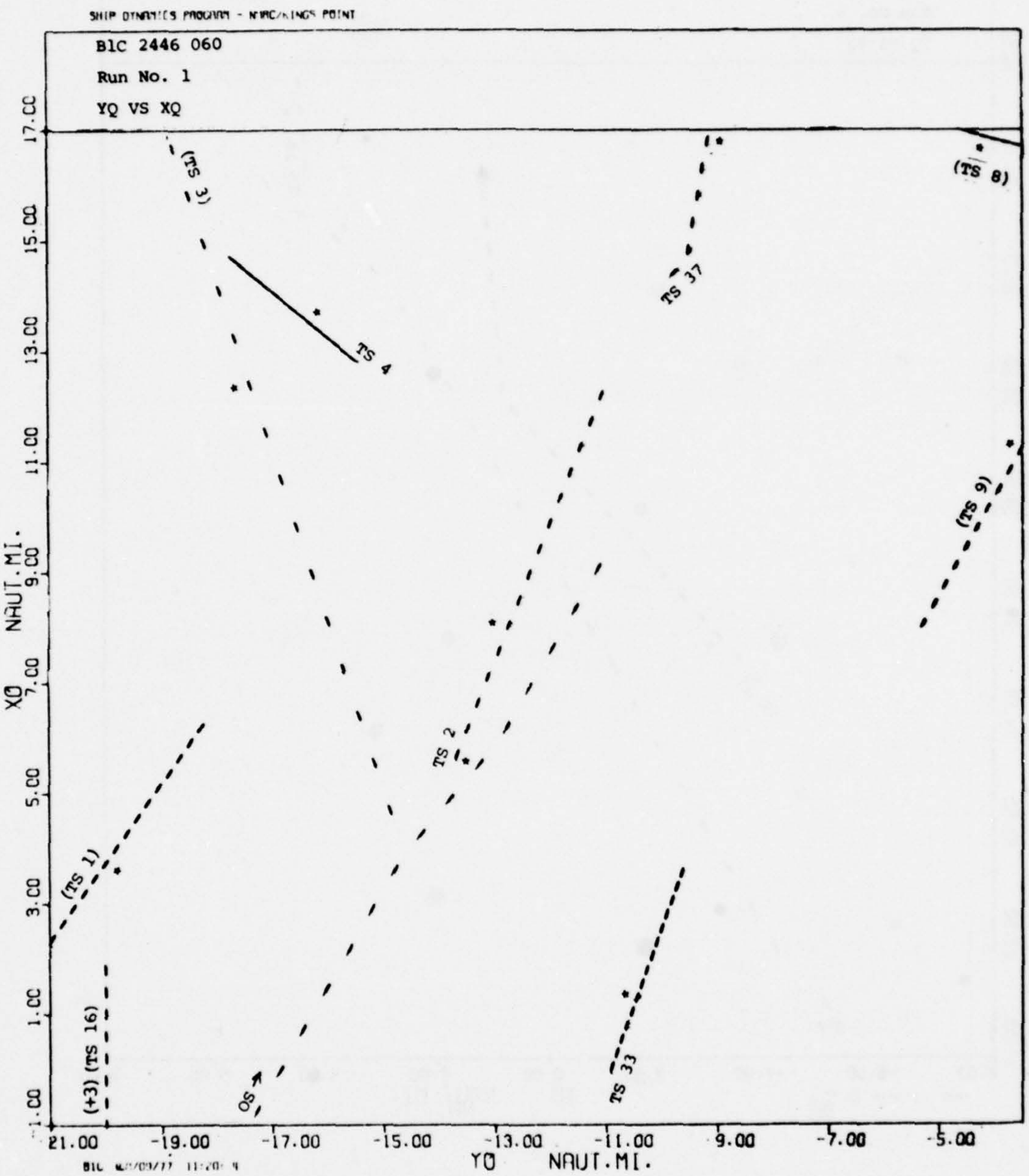
A1C 2449 060
Run No. 1
YO VS XO
OS
(TS 14)
TS 2
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
XO NAUT.MI.
-33.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
YO NAUT.MI.


SHIP DYNAMICS PROGRAM - NPSC/KINGS POINT
A2C 2449 060
Run No. 4
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
TS 26
TS 7
TS 8
TS 9
TS 1
(TS 19)
TS 38
TS 13
TS 16
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-3.00
-5.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5.00

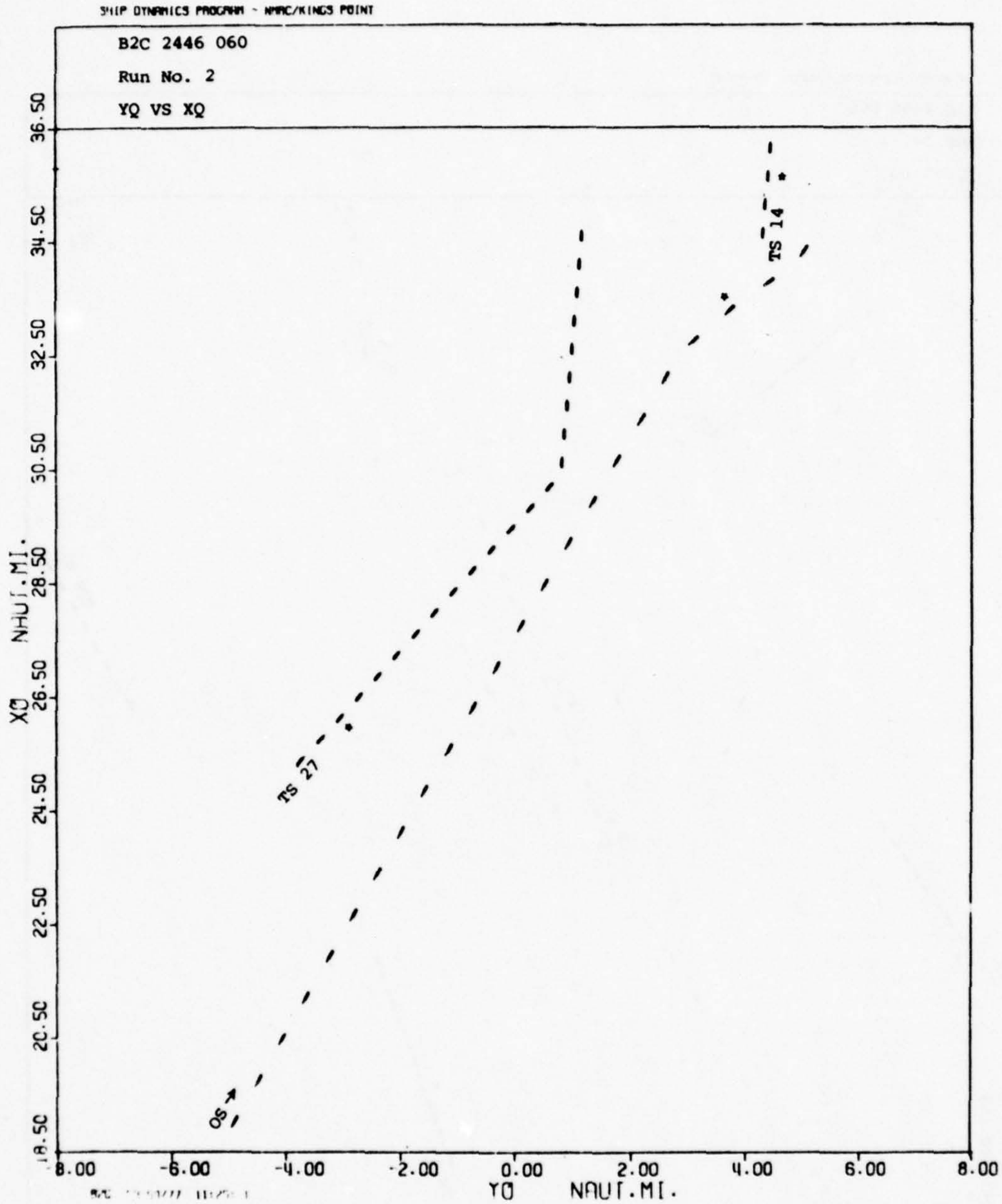


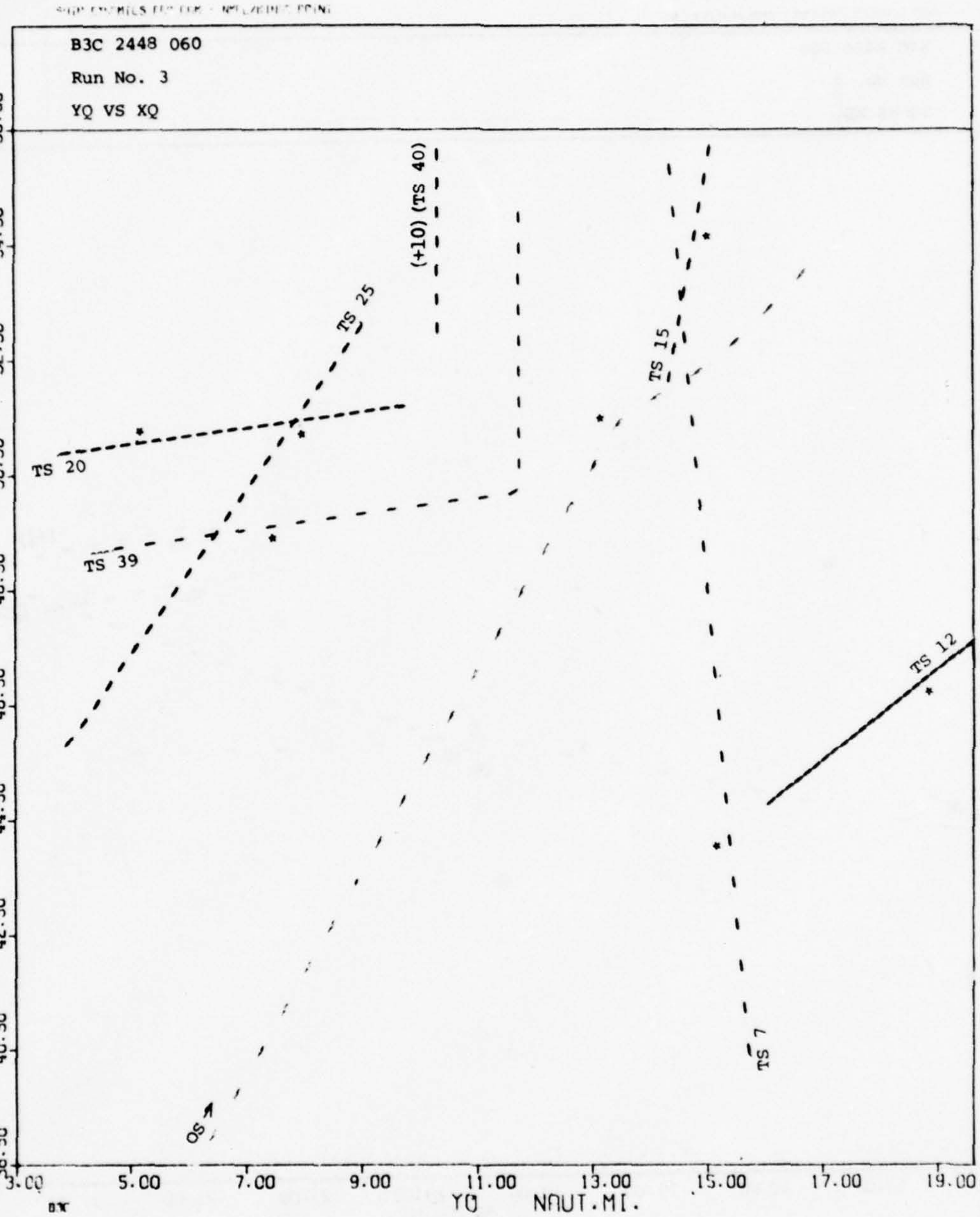
SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A3C 2449 060
Run No. 6
YQ VS XQ
OS
TS 3
TS 28
TS 15
XO NAUT.MI.
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-8.00
-5.00
-2.00
1.00
4.00
7.00
10.00
13.00
16.00
YO NAUT.MI.

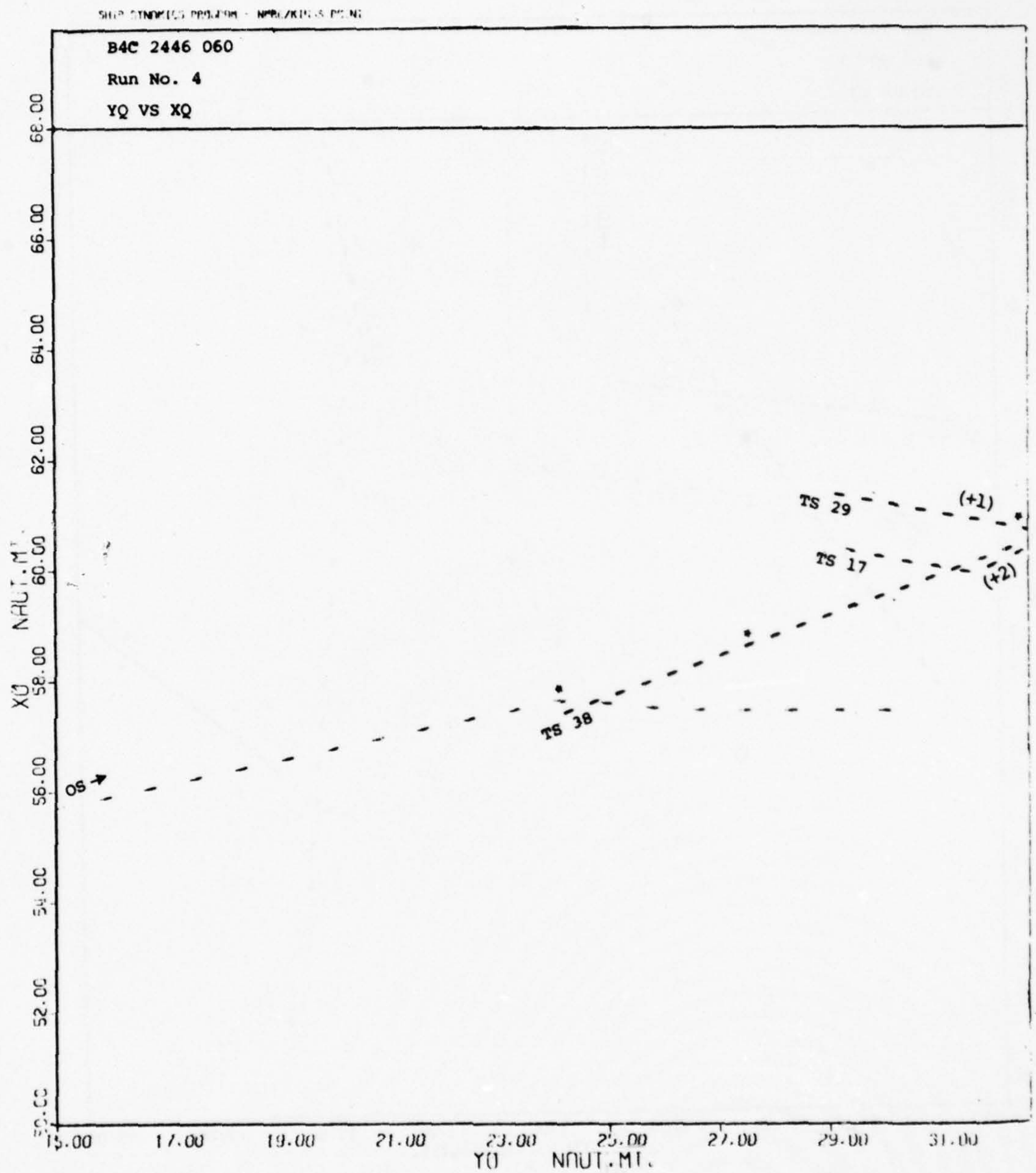

A4C 2449 060
Run No. 7
YQ VS XQ
XO NAUT.MI.
YO NAUT.MI.
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-27.00
-30.00
-33.00
-36.00
18.00
16.00
19.00
22.00
25.00
28.00
31.00
34.00
37.00
(+3) (TS 27)
OS
TS 39
TS 25
TS 4
TS 37
TS 21

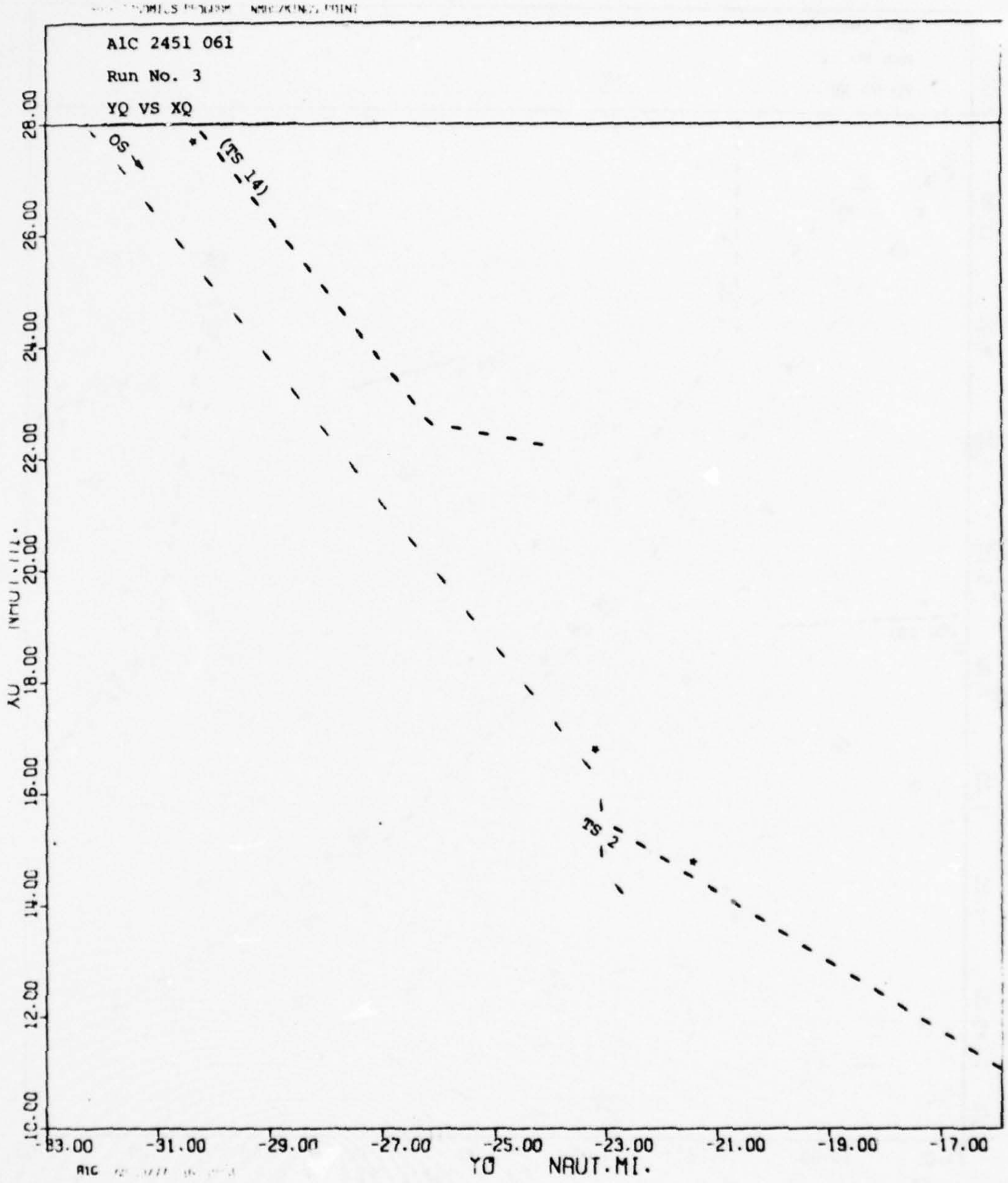

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B1C 2446 060
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5.00
(TS 3)
(TS 8)
TS 37
TS 4
(TS 9)
TS 2
(TS 1)
(+3) (TS 16)
OS
TS 33

1

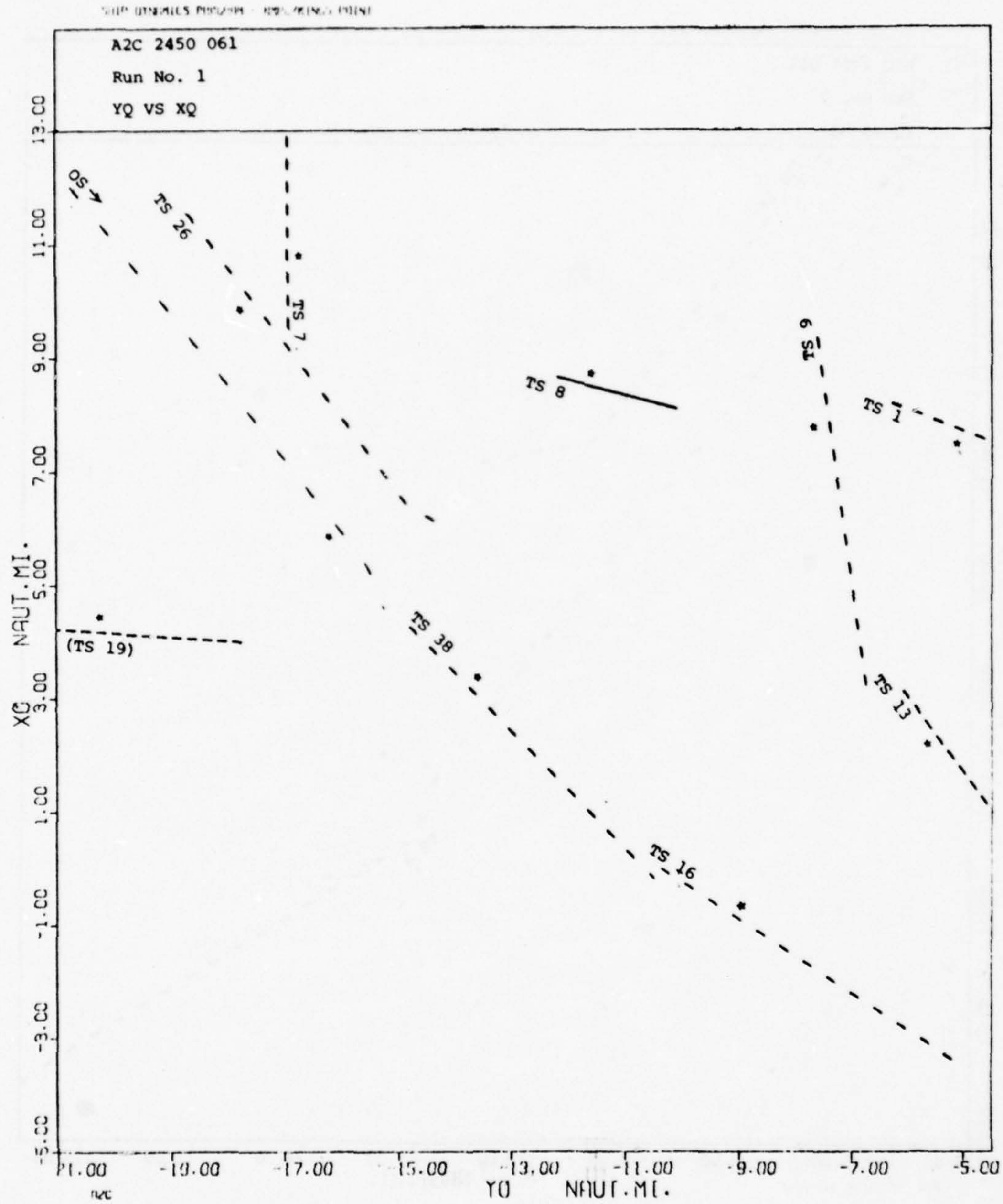

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B2C 2446 060
Run No. 2
YQ VS XQ
TS 14
TS 27
OS
XQ NAUT.MI.
YQ NAUT.MI.
36.50
34.50
32.50
30.50
28.50
26.50
24.50
22.50
20.50
18.50
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00

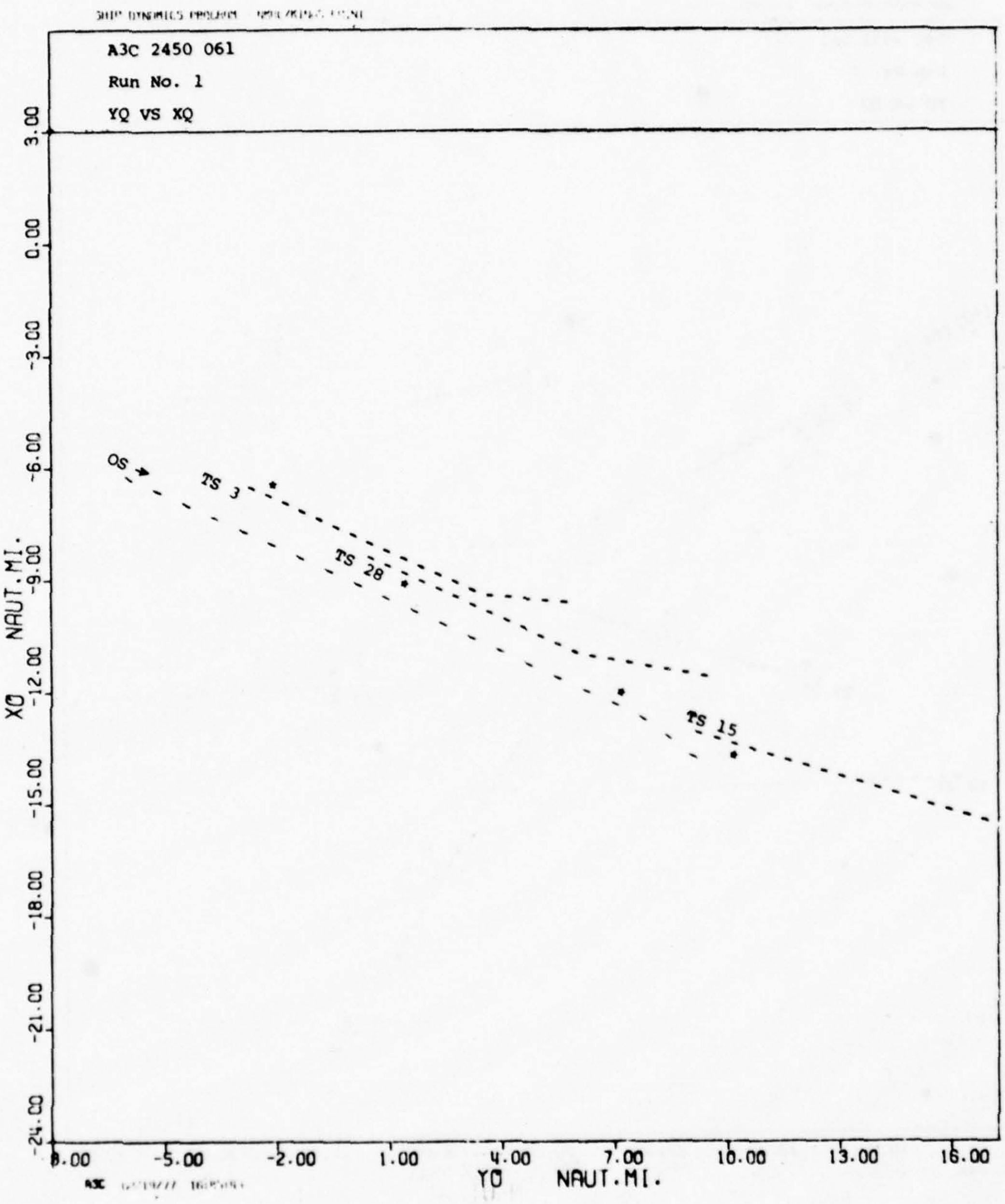

B3C 2448 060
Run No. 3
YQ VS XQ
56.50
54.50
52.50
50.50
48.50
46.50
44.50
42.50
40.50
38.50
3.00
5.00
7.00
9.00
11.00
13.00
15.00
17.00
19.00
XQ NAUT.MI.
YQ NAUT.MI.
(+10) (TS 40)
TS 25
TS 20
TS 39
TS 15
TS 12
TS 7
OS

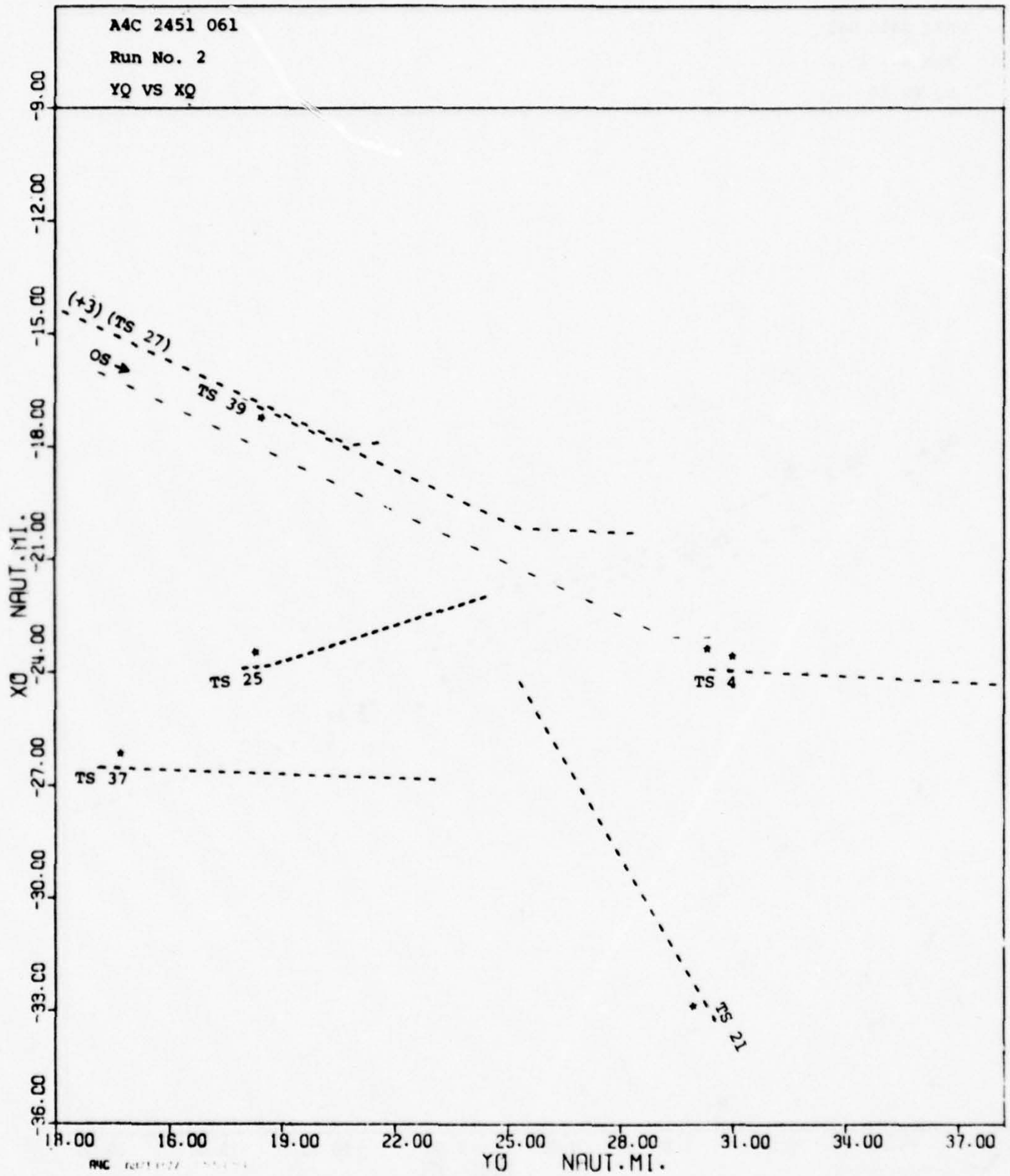

B4C 2446 060
Run No. 4
YQ VS XQ
OS
TS 38
TS 29
TS 17
(+1)
(+2)
XQ NAUT.MI.
YQ NAUT.MI.
56.00
58.00
60.00
62.00
64.00
66.00
68.00
52.00
17.00
19.00
21.00
23.00
25.00
27.00
29.00
31.00

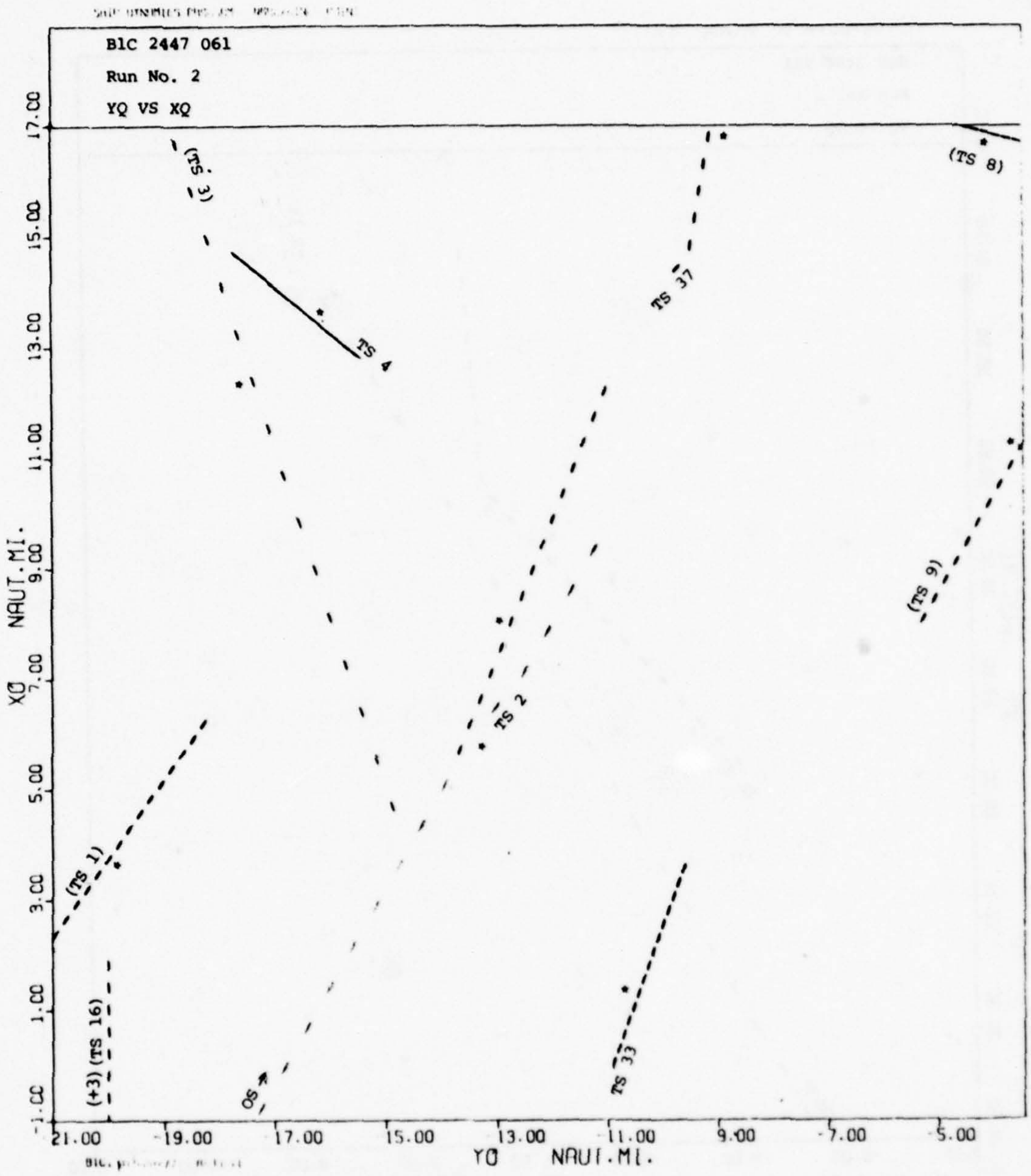


A1C 2451 061
Run No. 3
YQ VS XQ
OS
(TS 14)
TS 2
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
-33.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
YO NAUT.MI.

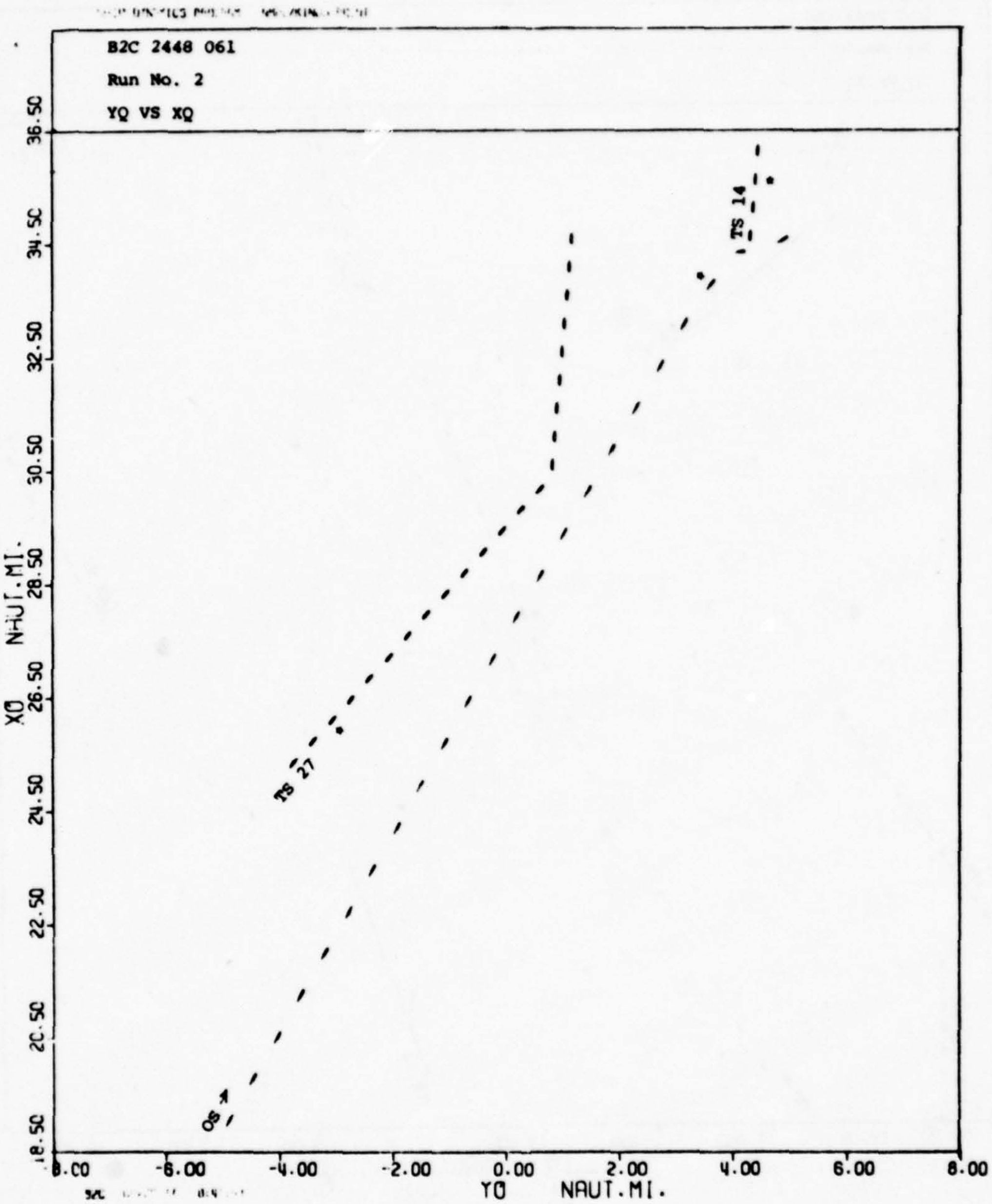

A2C 2450 061
Run No. 1
YQ VS XQ
OS
TS 26
TS 7
TS 8
TS 9
TS 1
TS 38
TS 13
TS 16
(TS 19)
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-3.00
-5.00
XQ NAUT.MI.
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5.00
YQ NAUT.MI.


A3C 2450 061
Run No. 1
YQ VS XQ
OS
TS 3
TS 28
TS 15
XO NAUT.MI.
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-8.00
-5.00
-2.00
1.00
4.00
7.00
10.00
13.00
16.00
YO NAUT.MI.

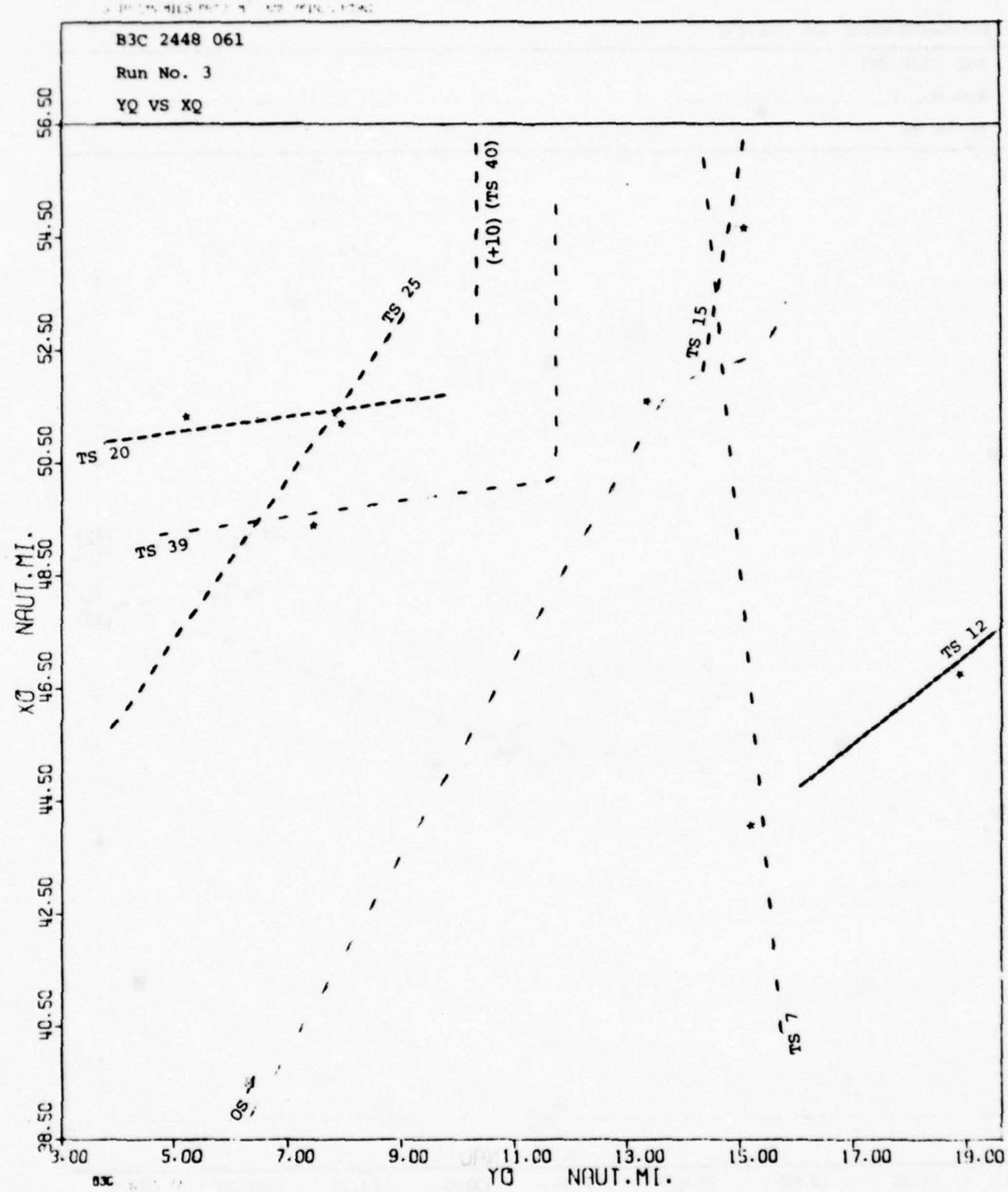

A4C 2451 061
Run No. 2
YQ VS XQ
(+3) (TS 27)
OS
TS 39
TS 25
TS 4
TS 37
TS 21
XQ NAUT.MI.
YQ NAUT.MI.
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-27.00
-30.00
-33.00
-36.00
16.00
19.00
22.00
25.00
28.00
31.00
34.00
37.00

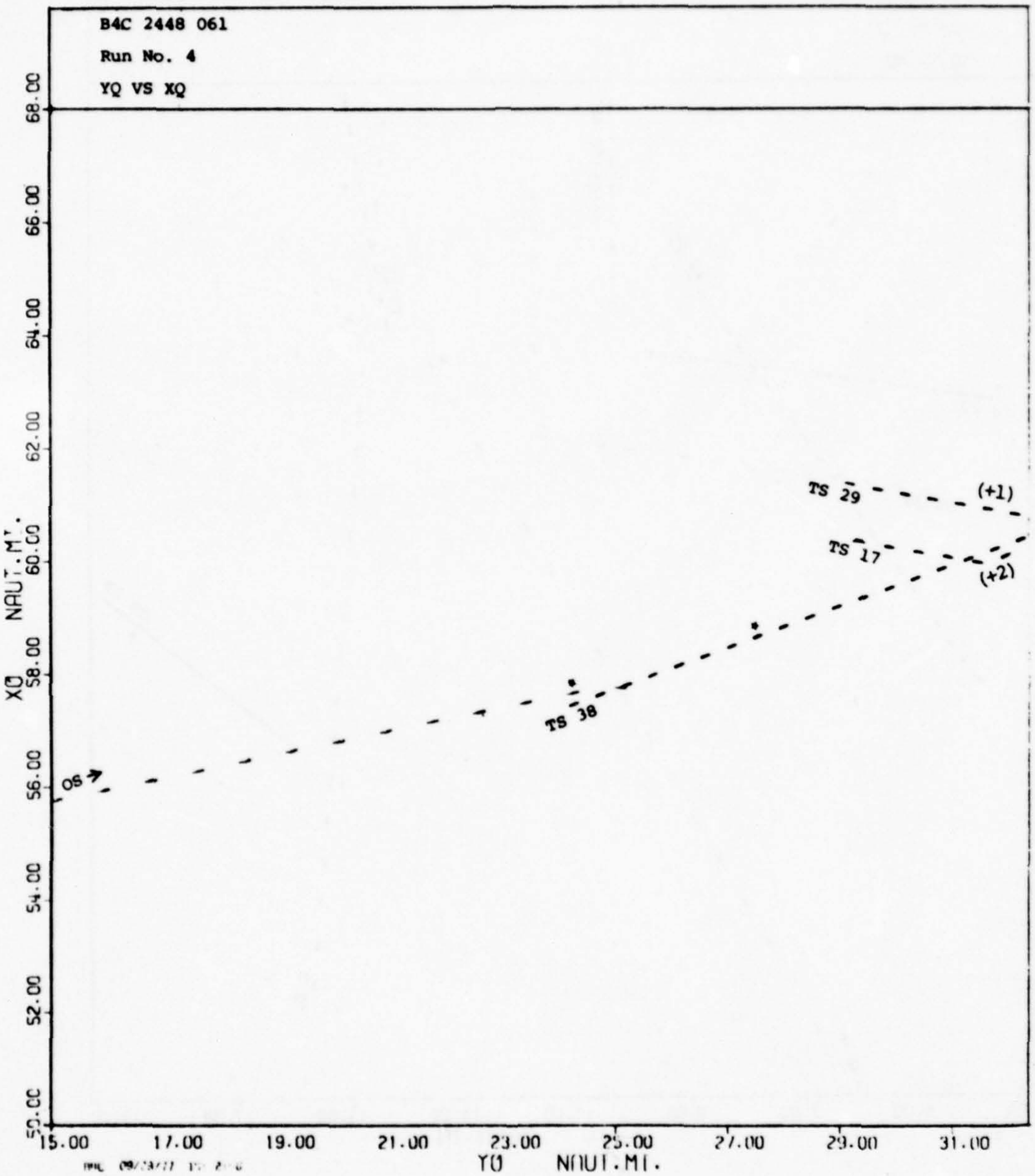


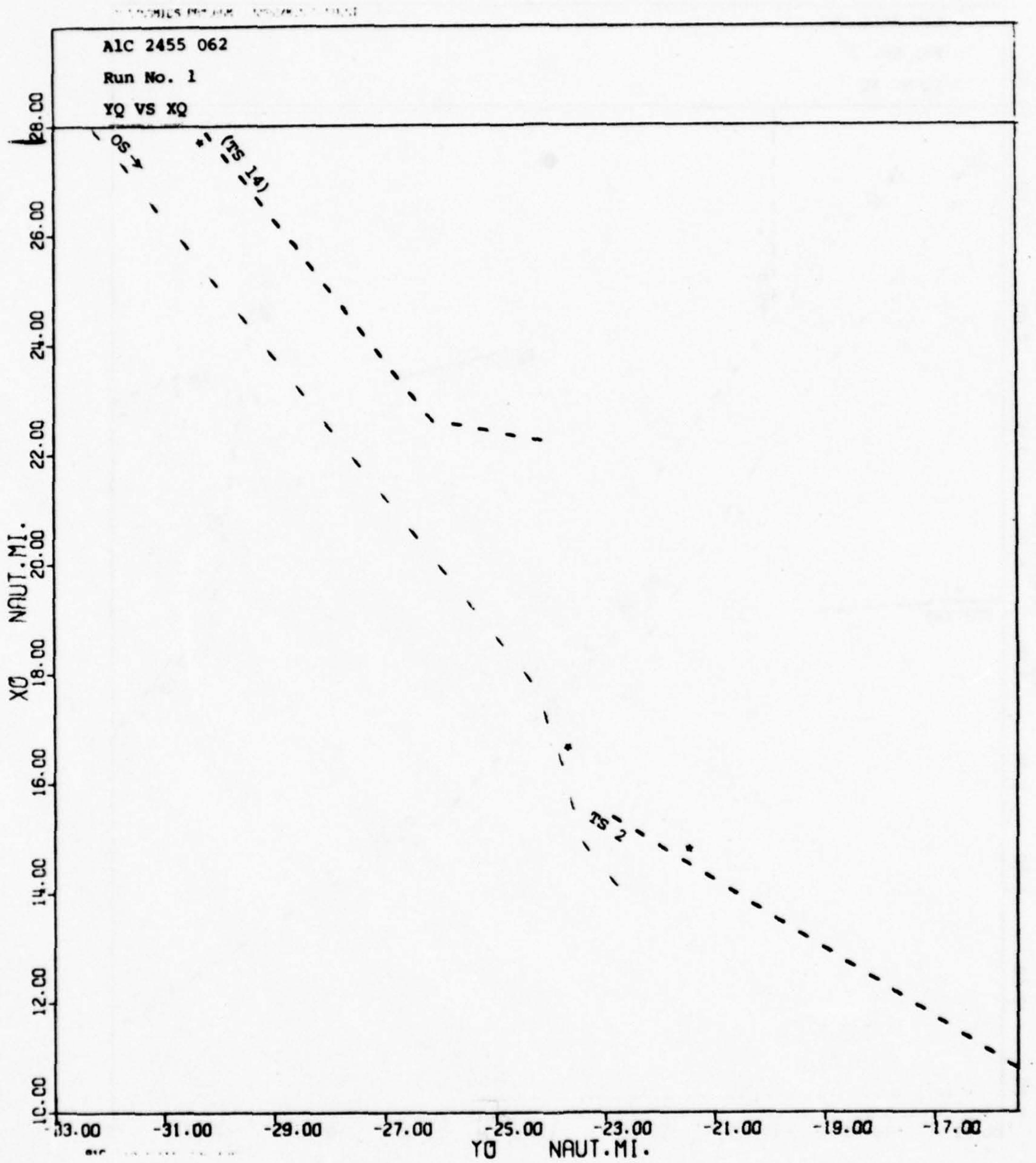
B1C 2447 061
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
-1.00
1.00
3.00
5.00
7.00
9.00
11.00
13.00
15.00
17.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5.00
(TS 3)
TS 4
TS 37
(TS 8)
(TS 9)
TS 2
(TS 1)
(+3) (TS 16)
OS
TS 33

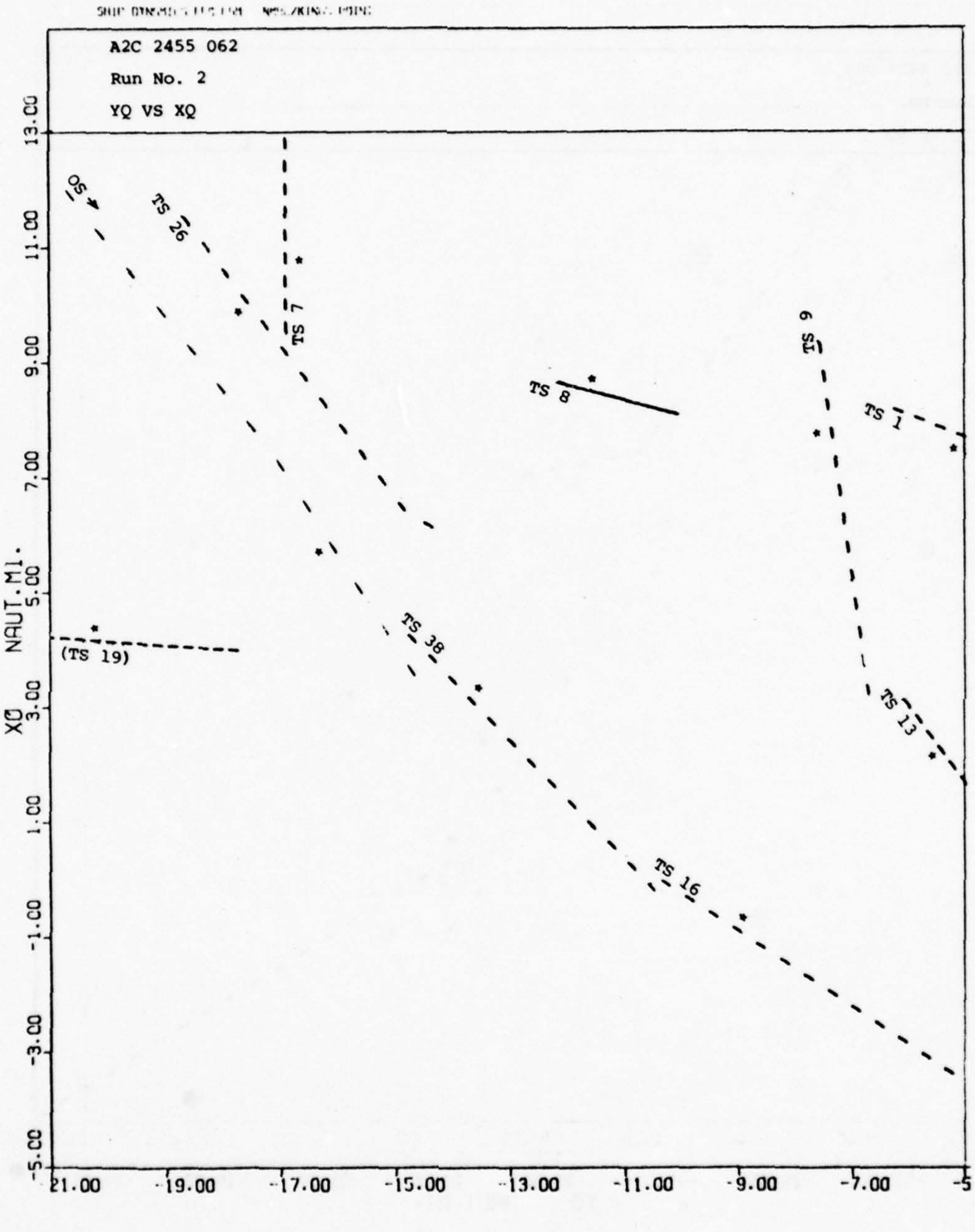


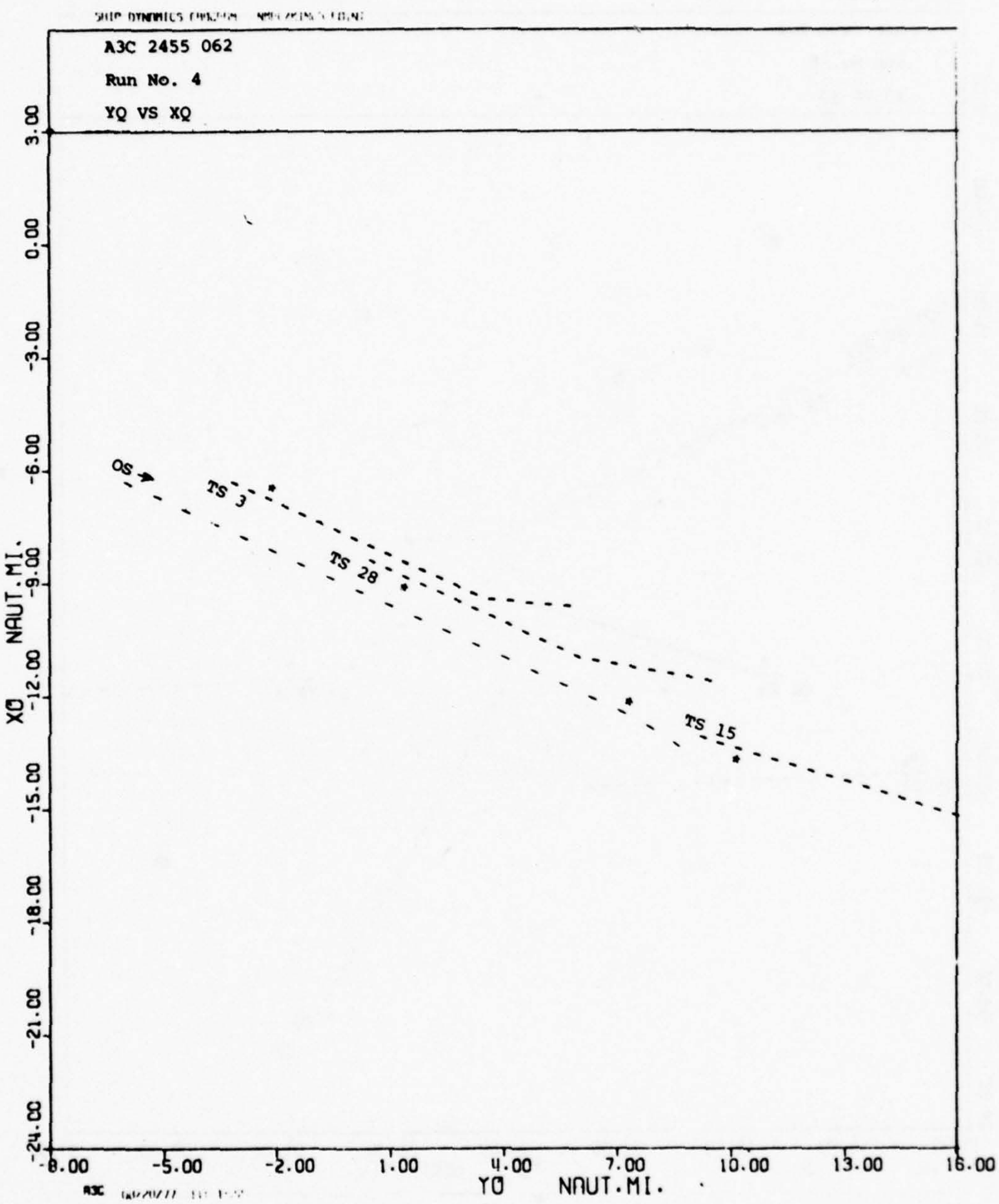
B2C 2448 061
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
36.50
34.50
32.50
30.50
28.50
26.50
24.50
22.50
20.50
18.50
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
TS 14
TS 27
OS

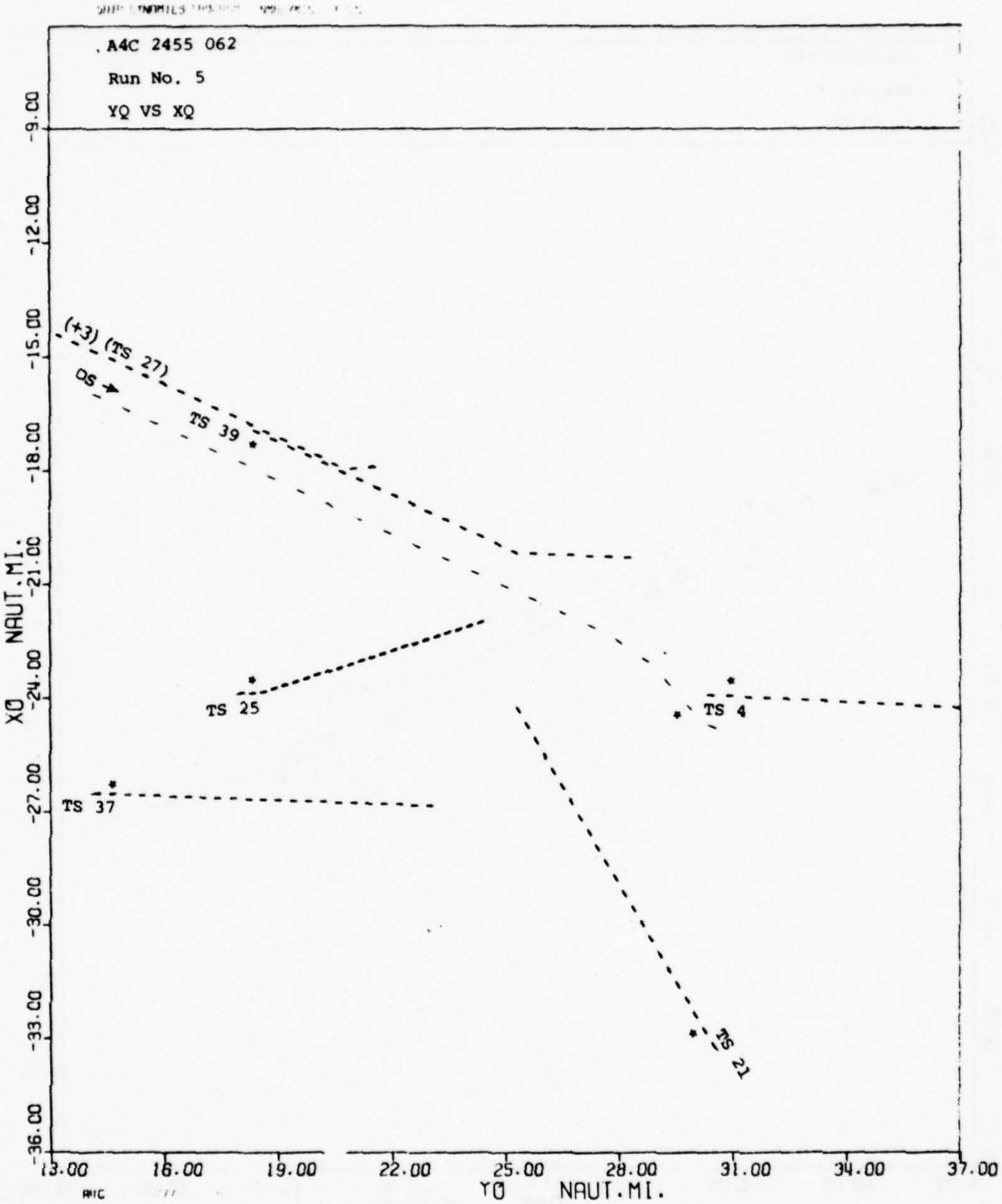

B3C 2448 061
Run No. 3
YQ VS XQ
(+10) (TS 40)
TS 25
TS 20
TS 39
TS 15
TS 12
TS 7
OS
XQ NAUT.MI.
YQ NAUT.MI.
38.50
40.50
42.50
44.50
46.50
48.50
50.50
52.50
54.50
56.50
3.00
5.00
7.00
9.00
11.00
13.00
15.00
17.00
19.00
B3C

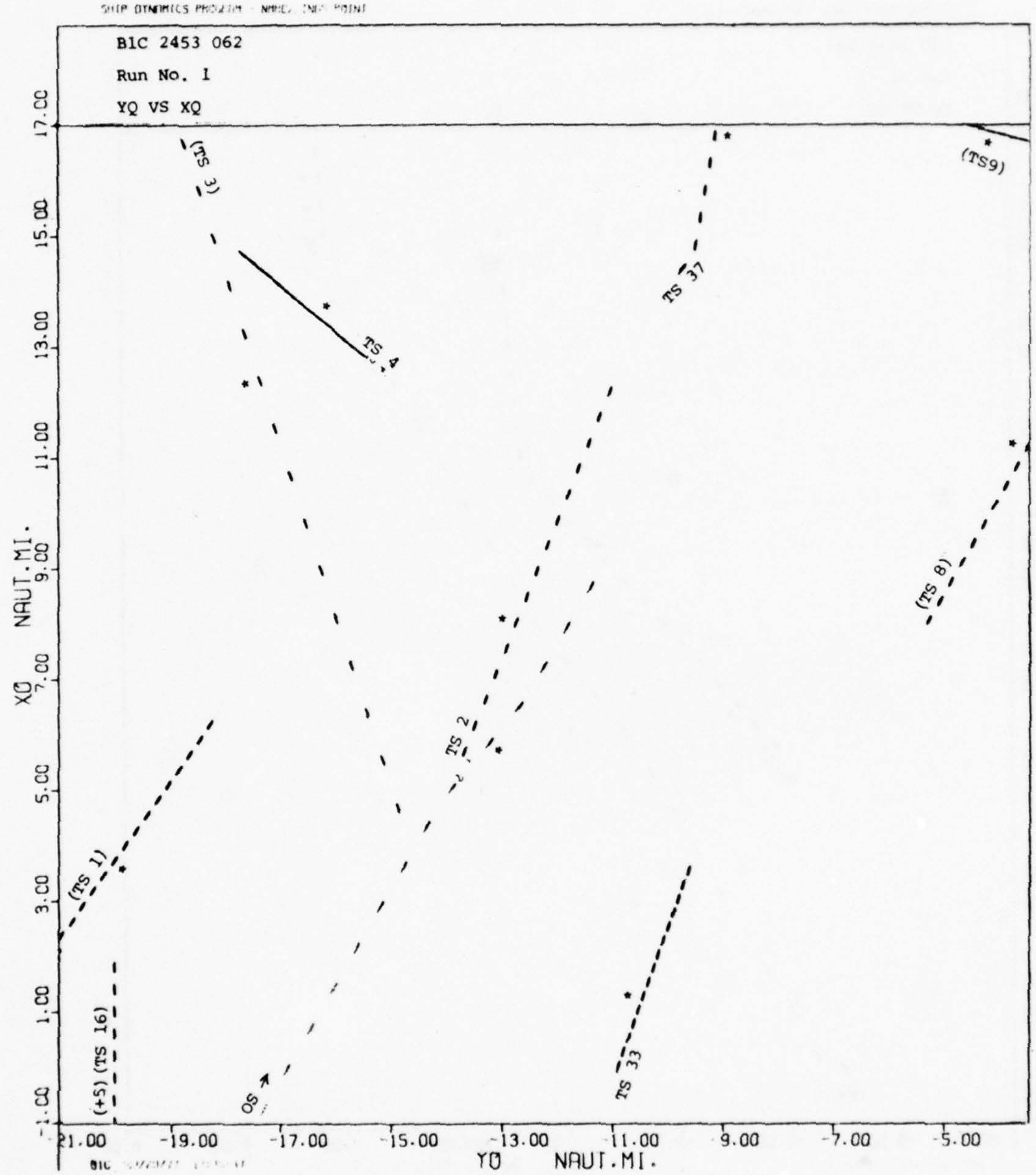

SHIP DYNAMICS PROGRAM - MARC/KINGS POINT
B4C 2448 061
Run No. 4
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
TS 38
TS 29
TS 17
(+1)
(+2)
68.00
66.00
64.00
62.00
60.00
58.00
56.00
54.00
52.00
50.00
15.00
17.00
19.00
21.00
23.00
25.00
27.00
29.00
31.00

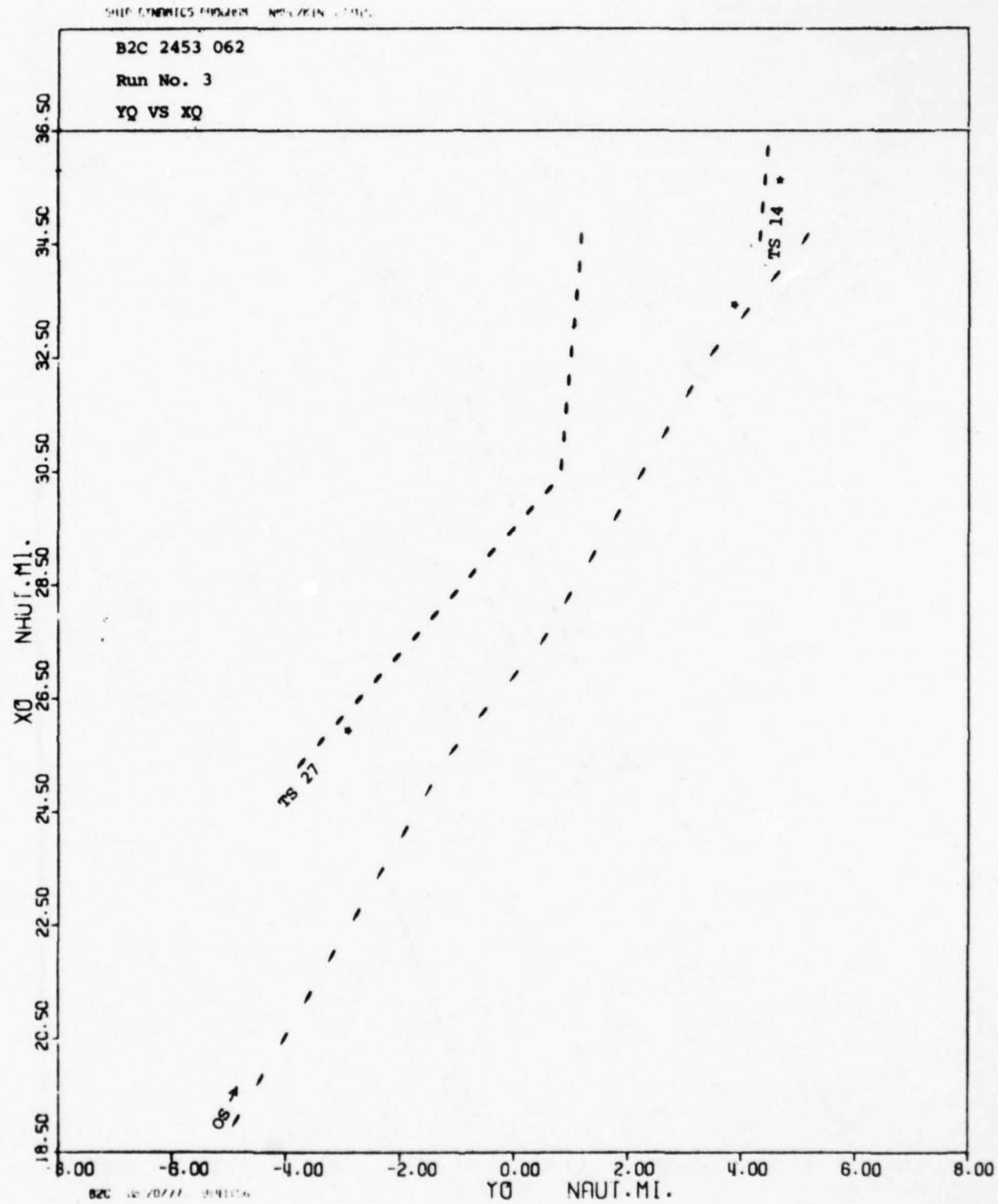

A1C 2455 062
Run No. 1
YQ VS XQ
OS
(TS 14)
TS 2
XO NAUT.MI.
YO NAUT.MI.
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
-33.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00

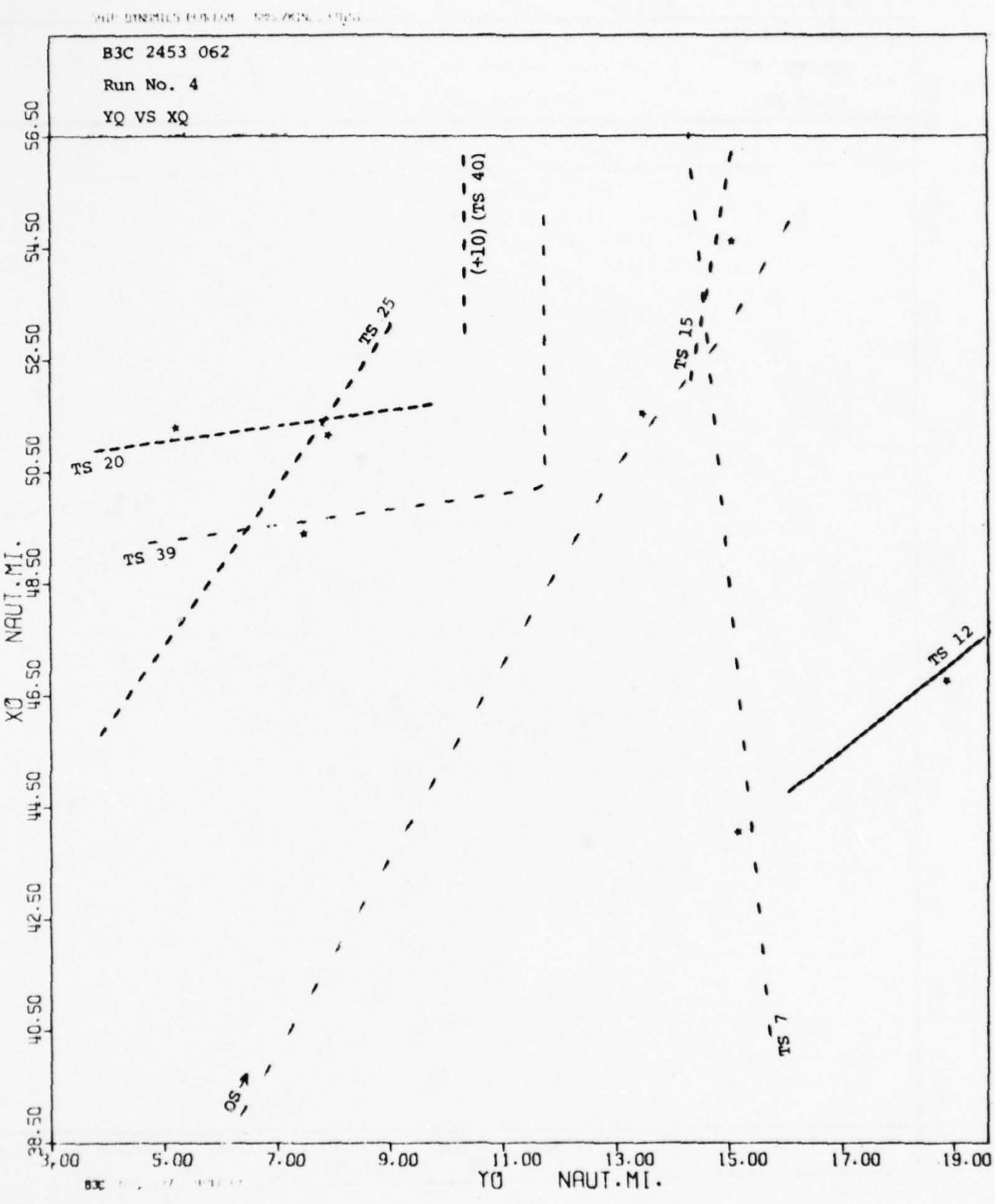

A2C 2455 062
Run No. 2
YQ VS XQ
XQ NAUT.MI.
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-3.00
-5.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5
OS
TS 26
TS 7
TS 8
TS 9
TS 1
(TS 19)
TS 38
TS 13
TS 16

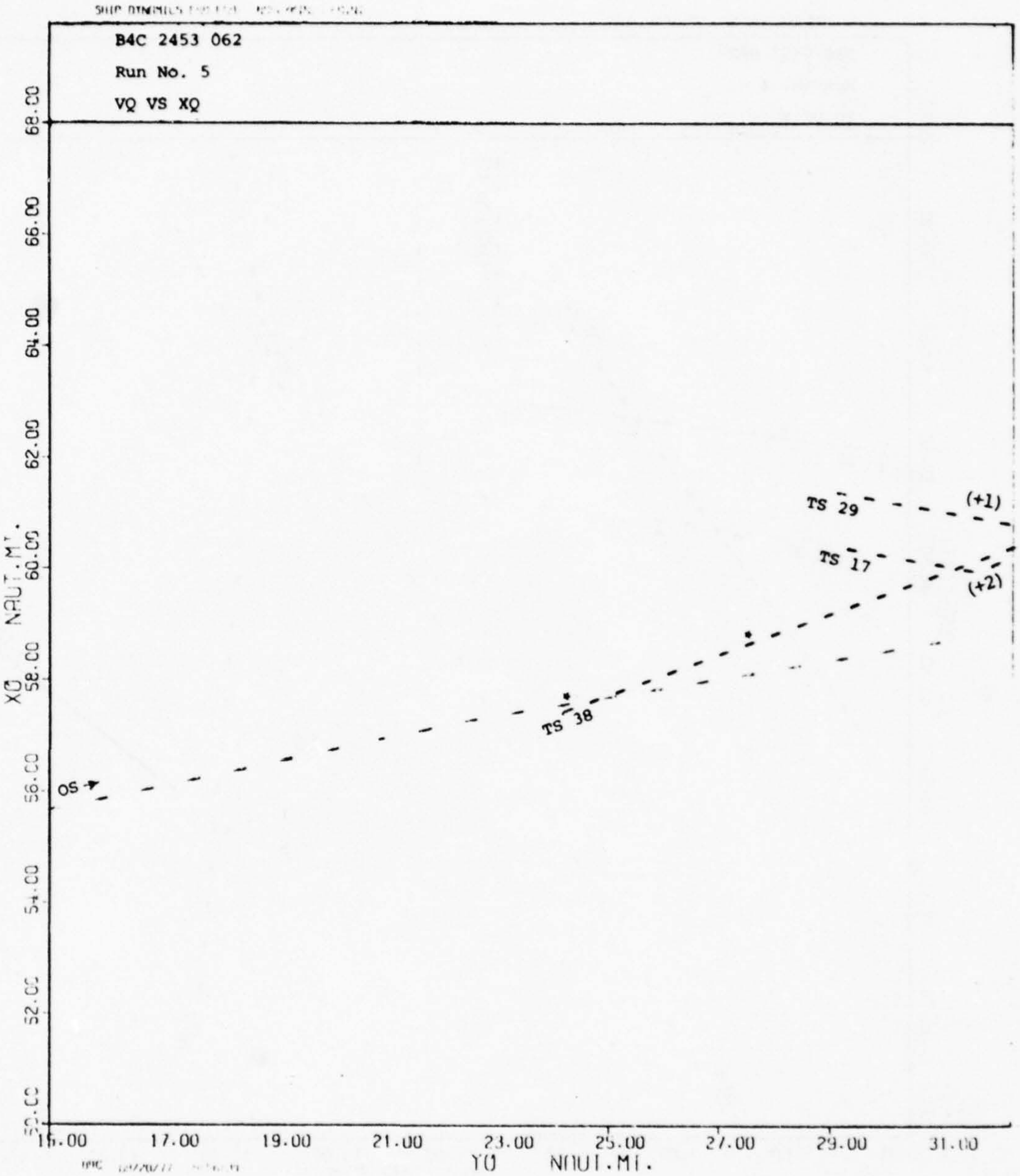

A3C 2455 062
Run No. 4
YQ VS XQ
OS
TS 3
TS 28
TS 15
XO NAUT.MI.
YO NAUT.MI.
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-8.00
-5.00
-2.00
1.00
4.00
7.00
10.00
13.00
16.00

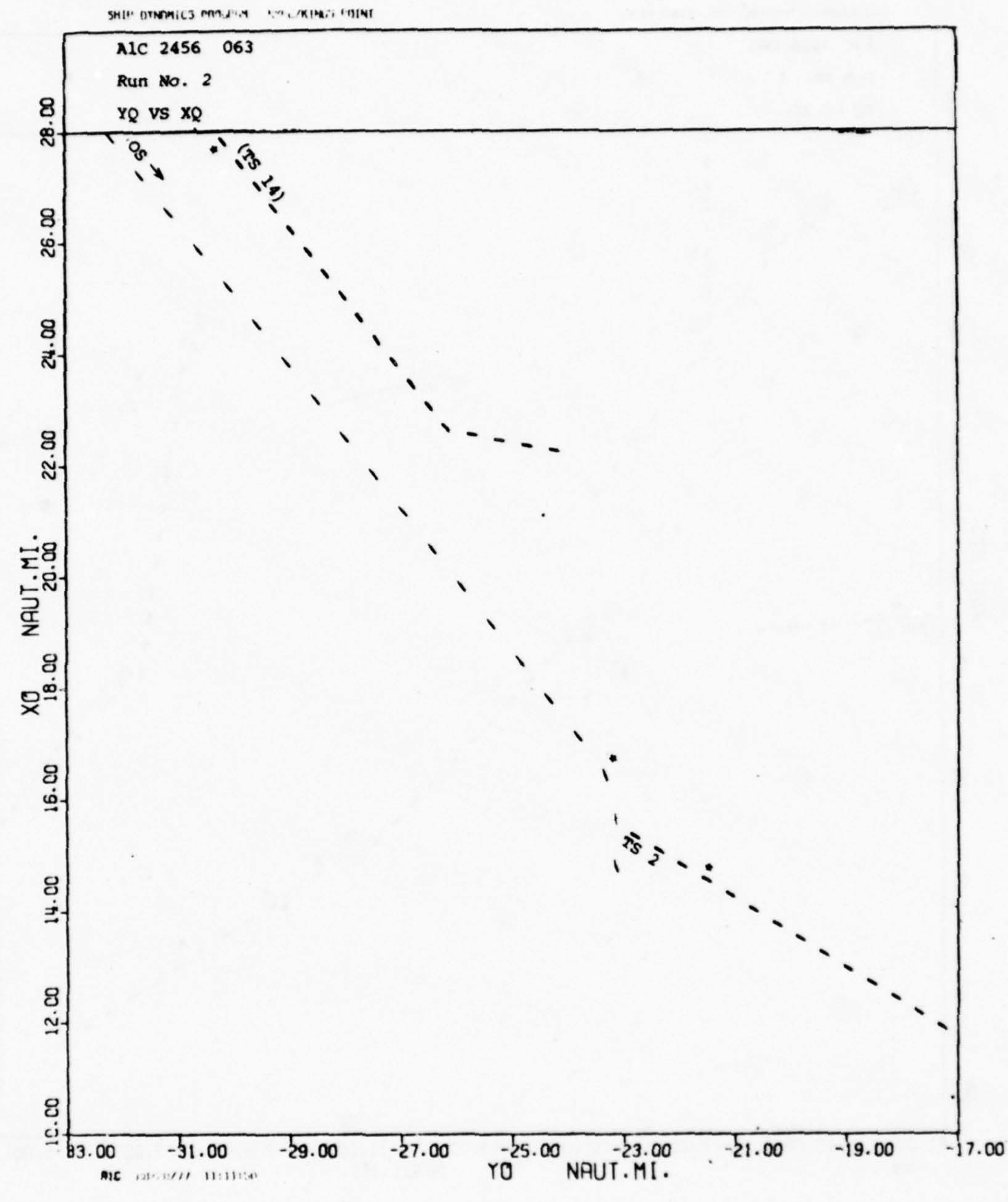

A4C 2455 062
Run No. 5
YQ VS XQ
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-27.00
-30.00
-33.00
-36.00
XQ NAUT.MI.
13.00
16.00
19.00
22.00
25.00
28.00
31.00
34.00
37.00
YQ NAUT.MI.
(+3) (TS 27)
OS
TS 39
TS 25
TS 4
TS 37
TS 21


B1C 2453 062
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5.00
(TS 3)
TS 4
TS 37
(TS9)
(TS 8)
TS 2
(TS 1)
(+5) (TS 16)
OS
TS 33

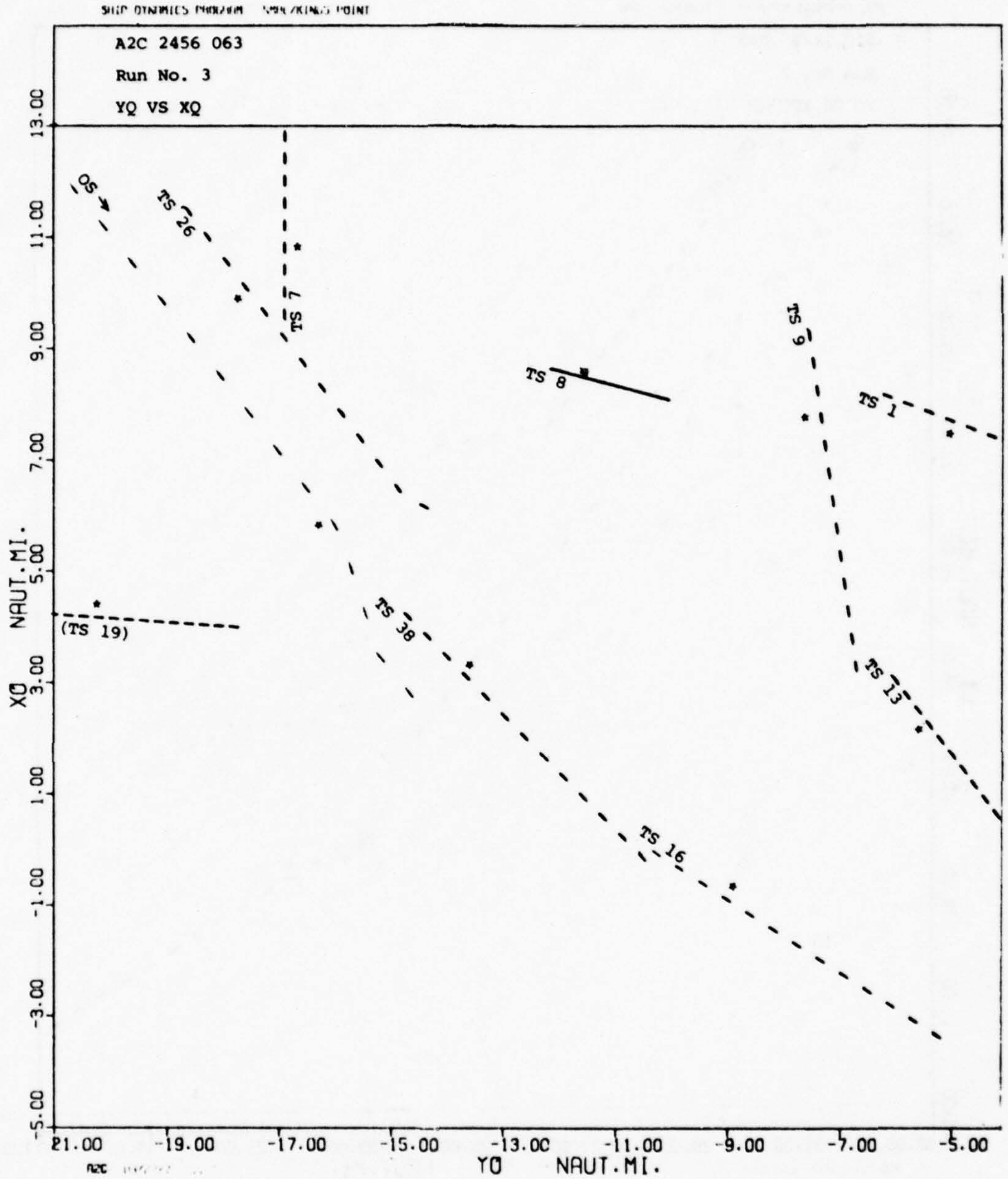

B2C 2453 062
Run No. 3
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
TS 27
TS 14
OS
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
34.50
36.50
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00


B3C 2453 062
Run No. 4
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
56.50
54.50
52.50
50.50
48.50
46.50
44.50
42.50
40.50
38.50
3.00
5.00
7.00
9.00
11.00
13.00
15.00
17.00
19.00
TS 20
TS 25
TS 39
(+10) (TS 40)
TS 15
TS 12
TS 7
OS

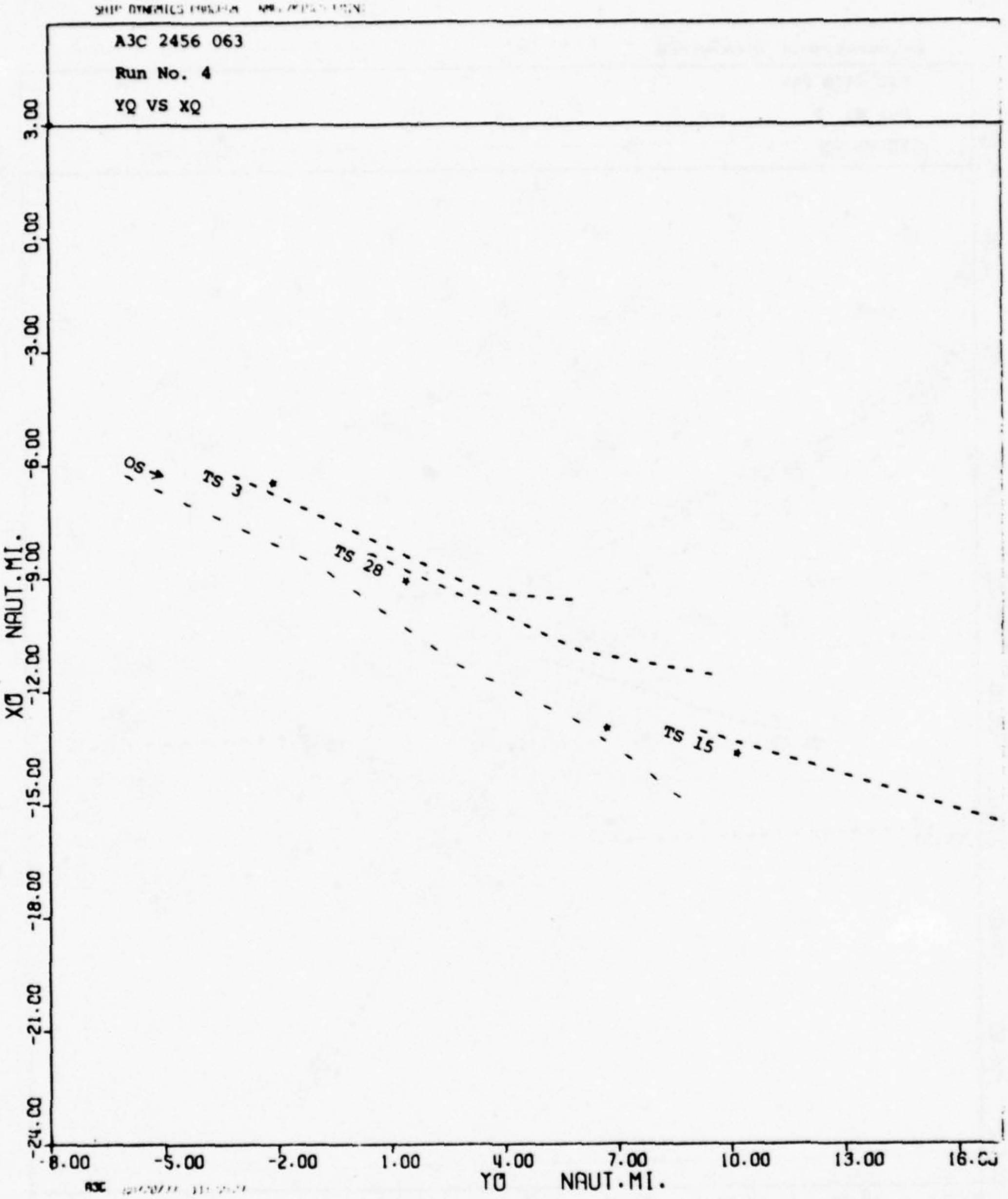

B4C 2453 062
Run No. 5
VQ VS XQ
68.00
66.00
64.00
62.00
60.00
58.00
56.00
54.00
52.00
50.00
XO NAUT.MI.
TS 29
(+1)
TS 17
(+2)
TS 38
OS
15.00
17.00
19.00
21.00
23.00
25.00
27.00
29.00
31.00
YO NAUT.MI.

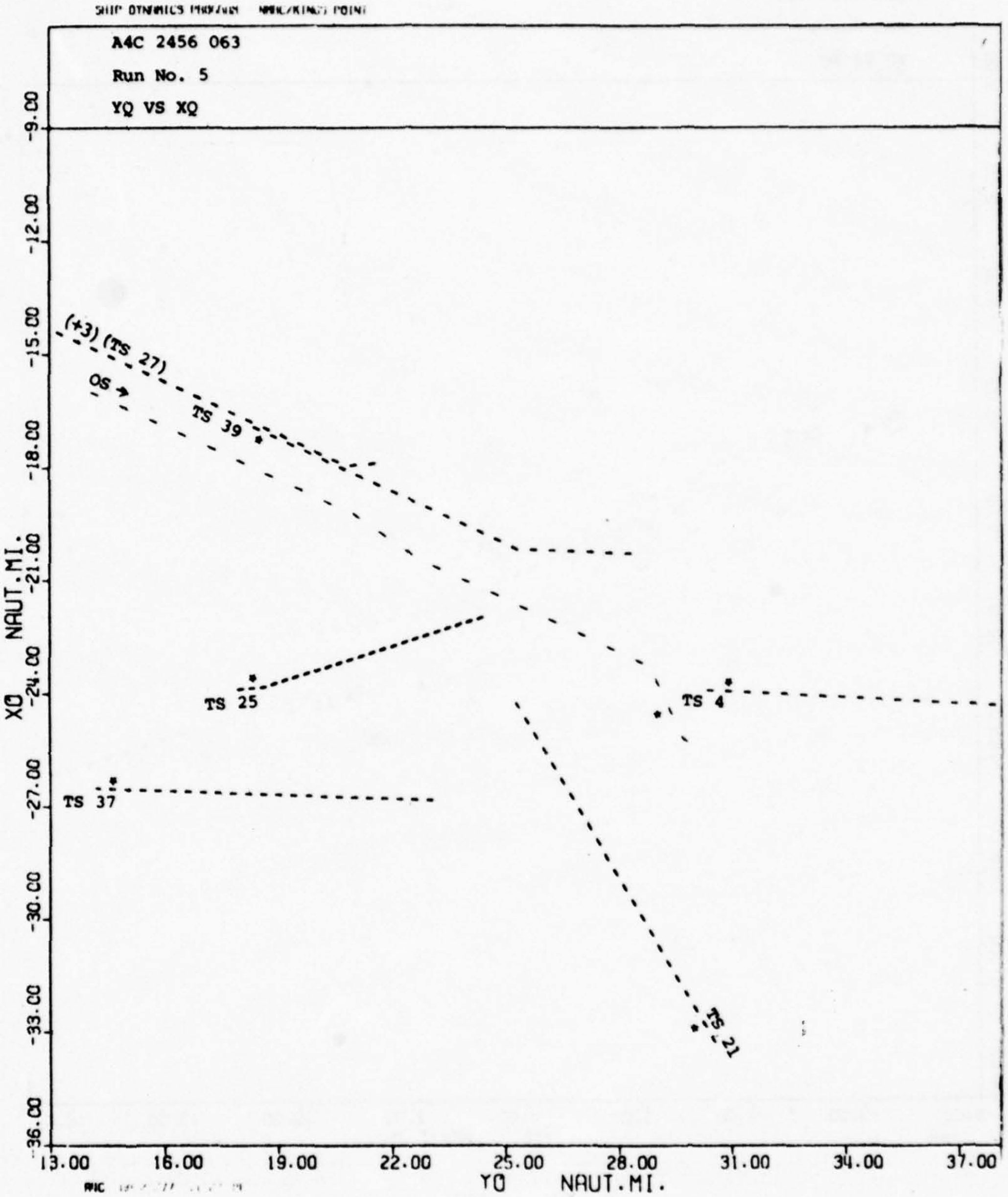


SHIP DYNAMICS PROGRAM
A1C 2456 063
Run No. 2
YQ VS XQ
OS
(TS 14)
TS 2
XQ NAUT.MI.
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
-33.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
YQ NAUT.MI.

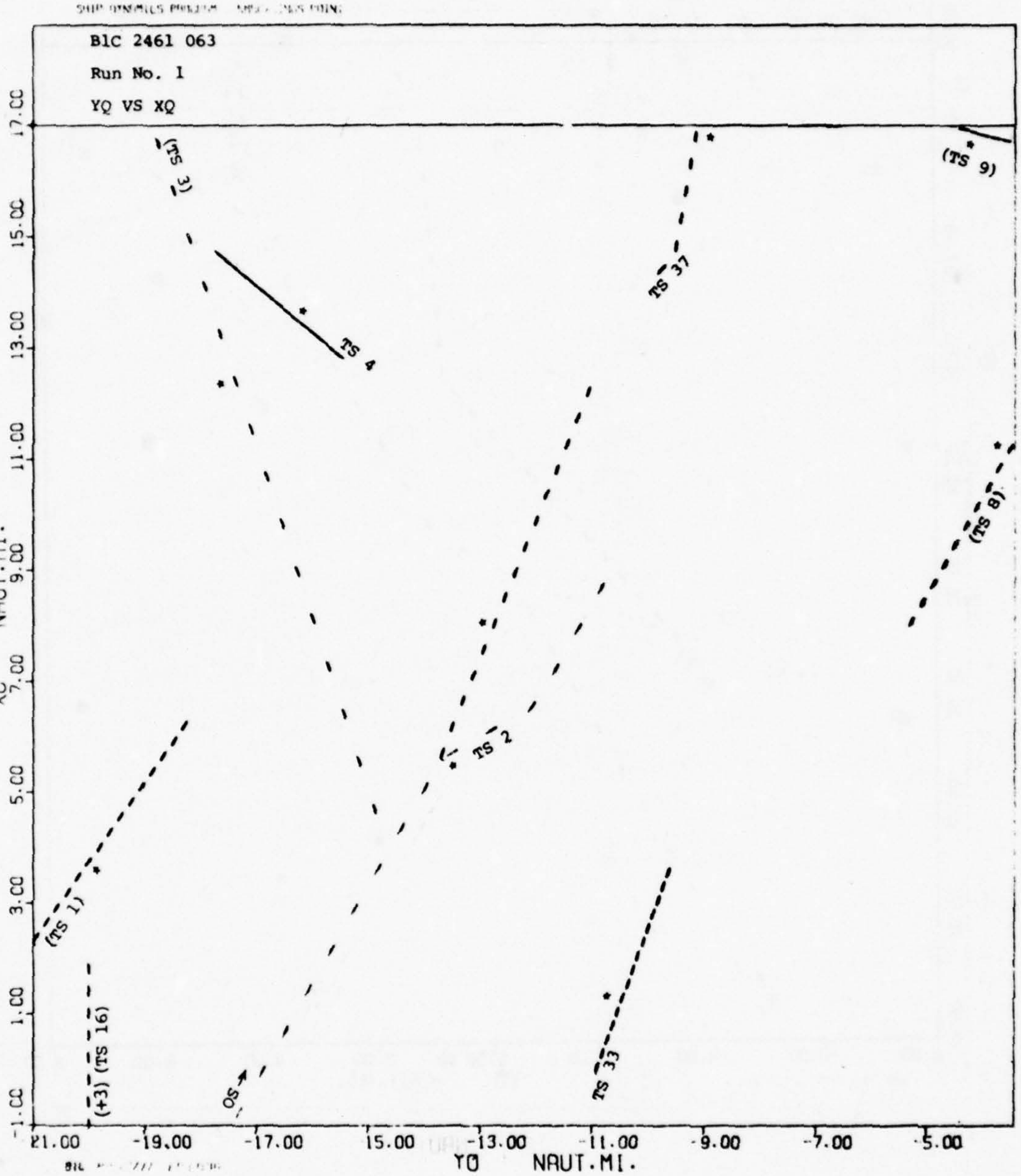


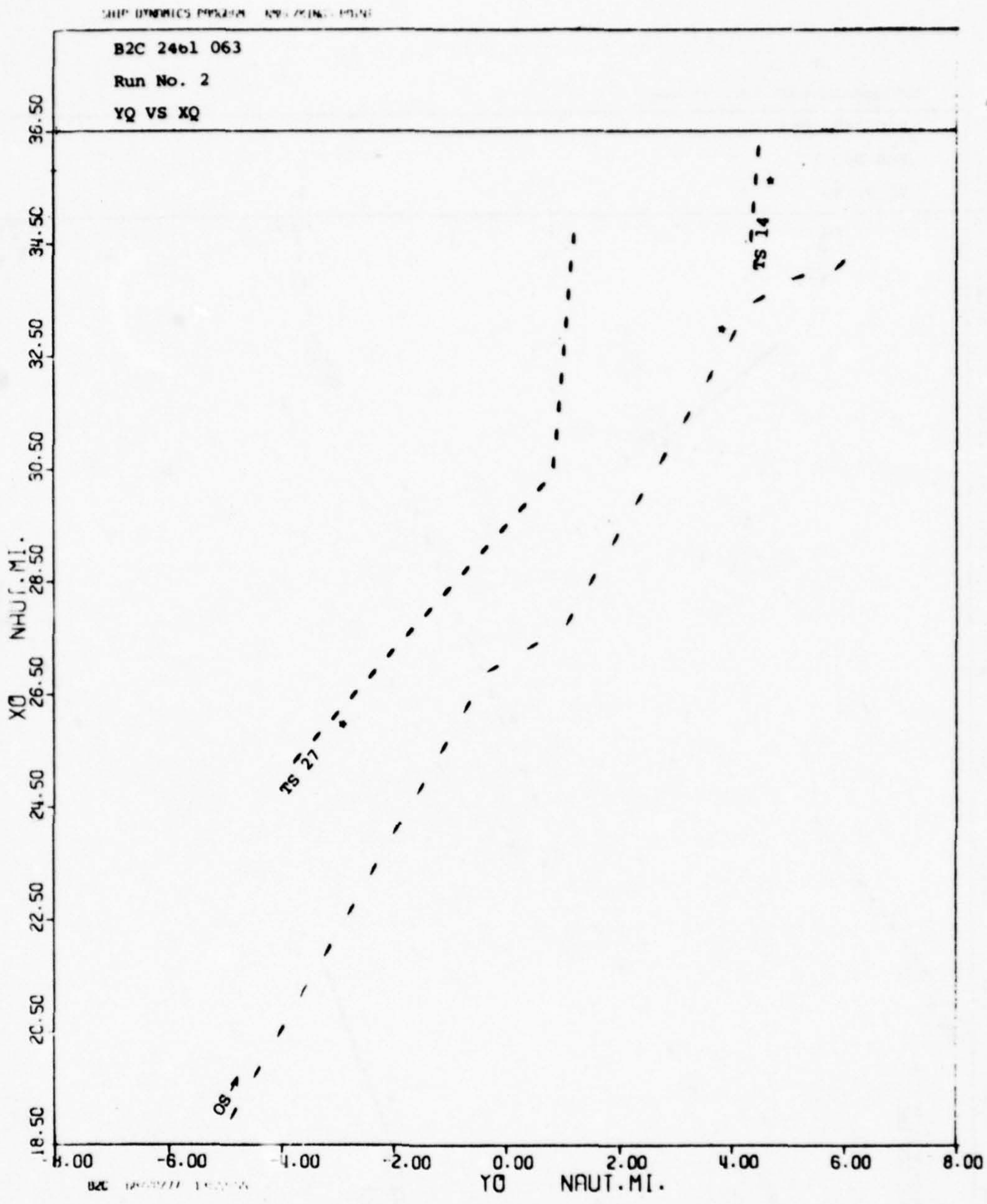
SHIP DYNAMICS PROGRAM NMRC/KINGS POINT
A2C 2456 063
Run No. 3
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-3.00
-5.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5.00
OS
TS 26
TS 7
TS 8
TS 9
TS 1
(TS 19)
TS 38
TS 13
TS 16

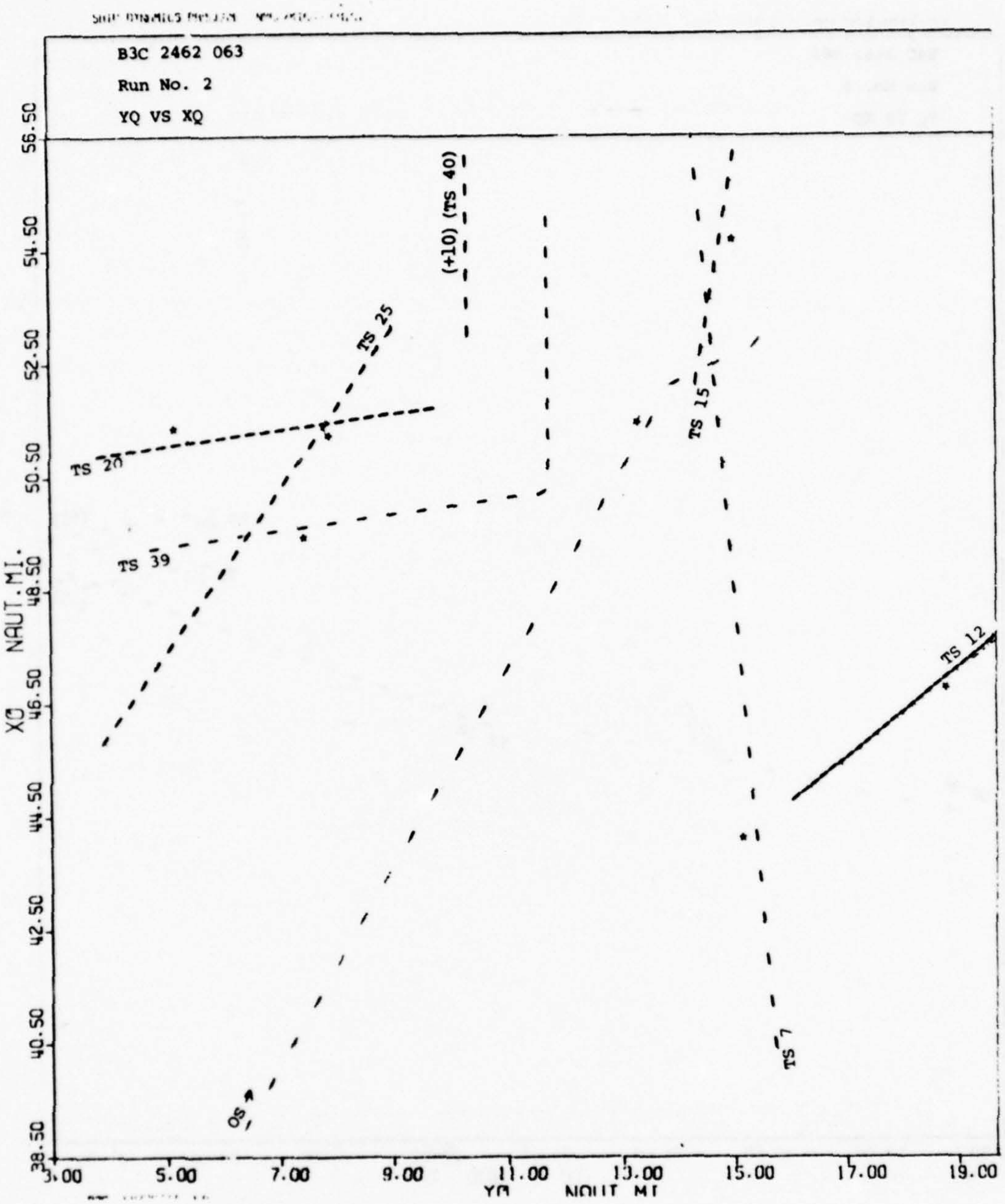

A3C 2456 063
Run No. 4
YQ VS XQ
OS
TS 3
TS 28
TS 15
XO NAUT.MI.
YO NAUT.MI.
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-8.00
-5.00
-2.00
1.00
4.00
7.00
10.00
13.00

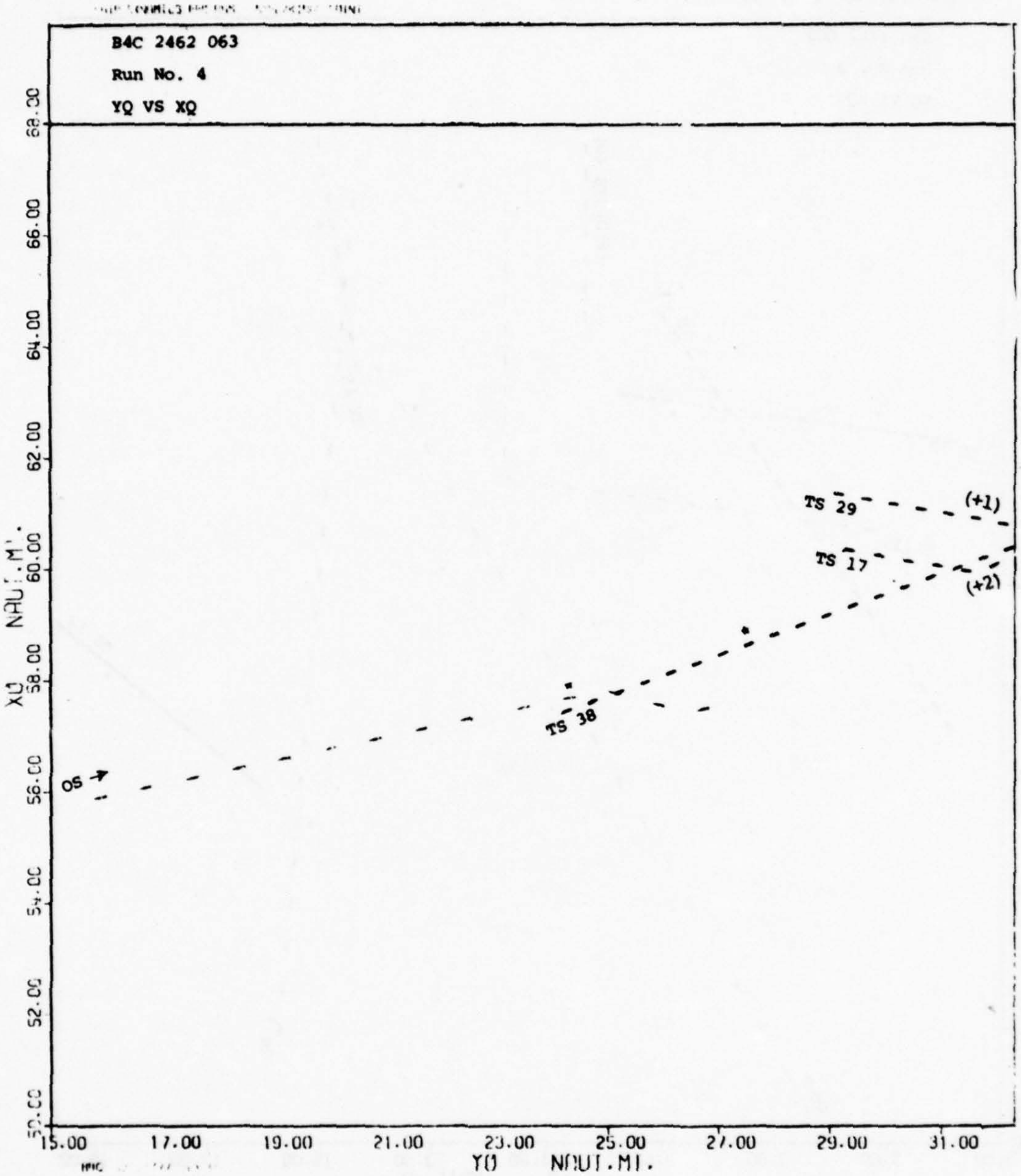


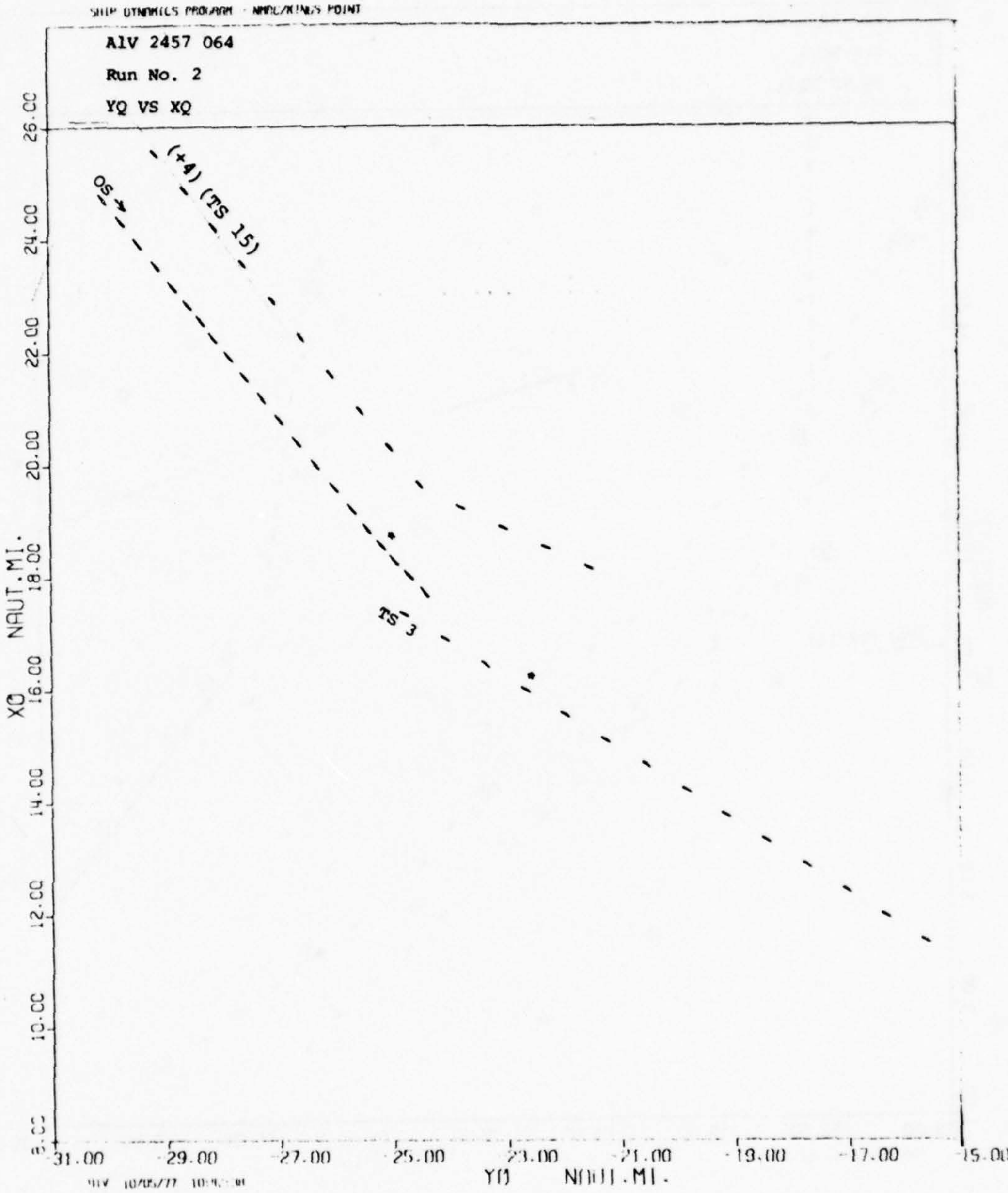
A4C 2456 063
Run No. 5
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-27.00
-30.00
-33.00
-36.00
13.00
16.00
19.00
22.00
25.00
28.00
31.00
34.00
37.00
(+3) (TS 27)
OS
TS 39
TS 25
TS 4
TS 37
TS 21


B1C 2461 063
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
(TS 3)
TS 4
TS 37
(TS 9)
(TS 8)
TS 2
(TS 1)
(+3) (TS 16)
OS
TS 33
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5.00

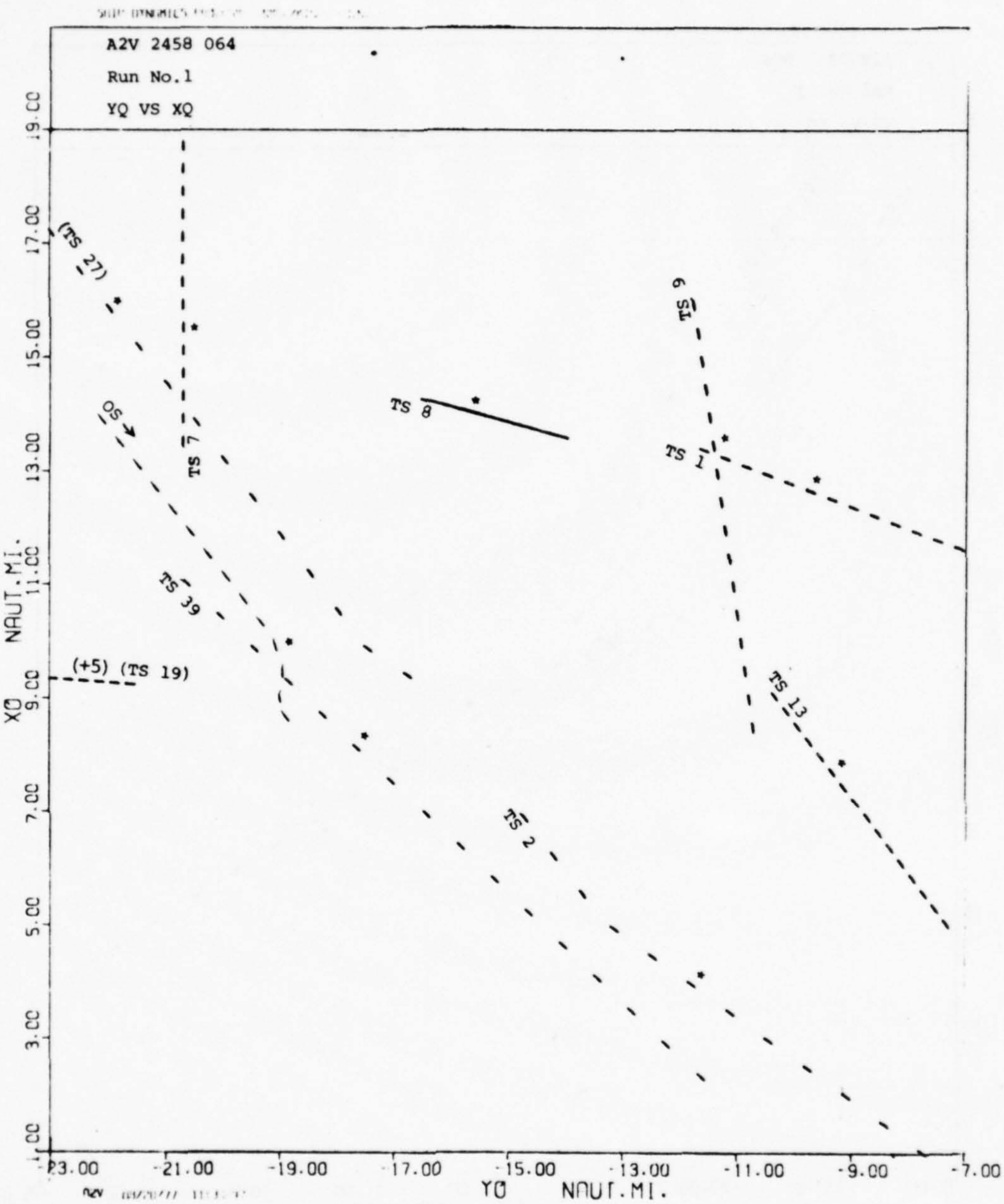

B2C 2461 063
Run No. 2
YQ VS XQ
TS 14
TS 27
OS
XQ NAUT.MI.
YQ NAUT.MI.
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
34.50
36.50
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00


B3C 2462 063
Run No. 2
YQ VS XQ
TS 25
(+10) (TS 40)
TS 20
TS 39
TS 15
TS 12
TS 7
OS
XQ NAUT.MI.
56.50
54.50
52.50
50.50
48.50
46.50
44.50
42.50
40.50
38.50
3.00
5.00
7.00
9.00
11.00
13.00
15.00
17.00
19.00

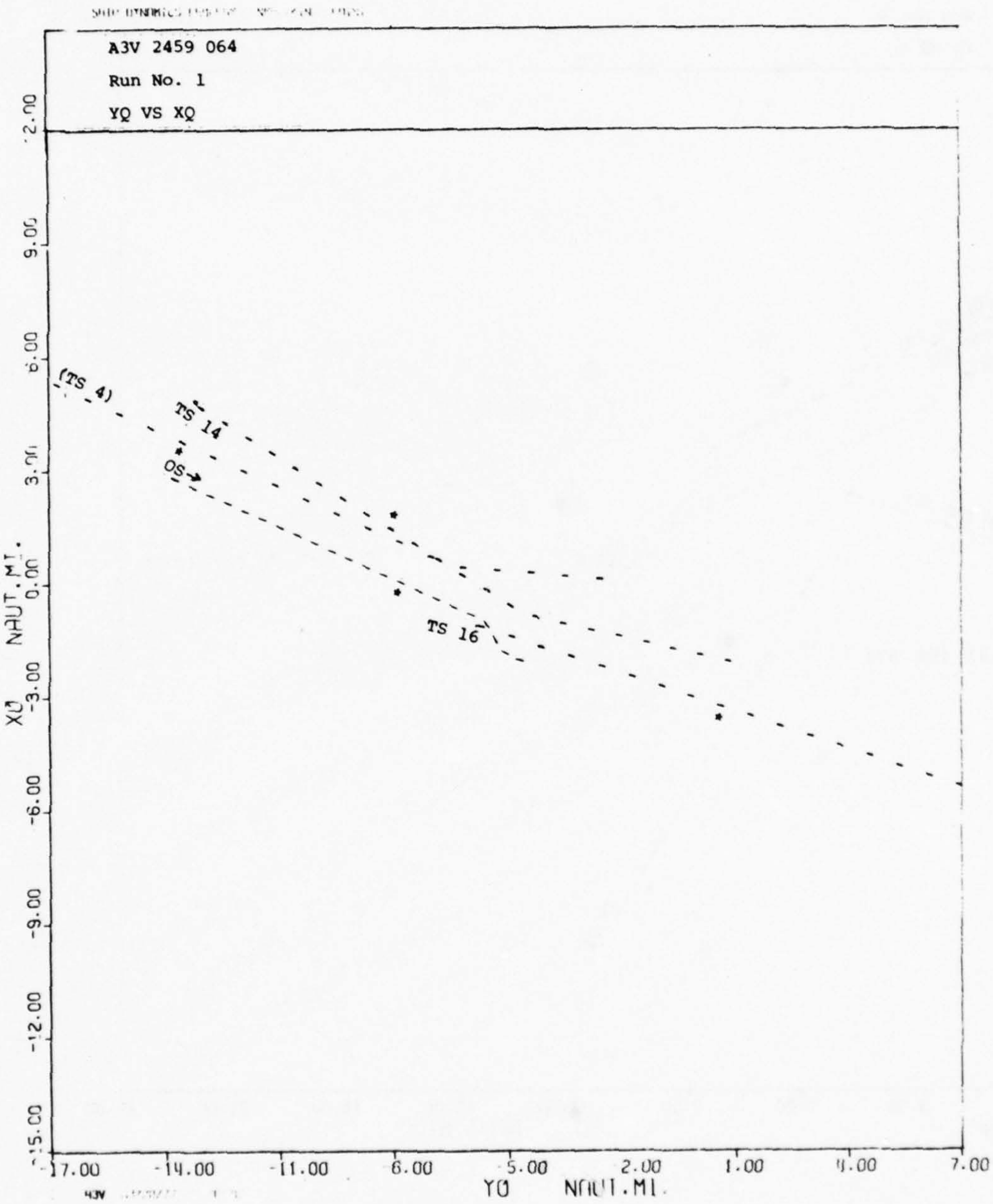

B4C 2462 063
Run No. 4
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
TS 38
TS 29
TS 17
(+1)
(+2)
68.00
66.00
64.00
62.00
60.00
58.00
56.00
54.00
52.00
50.00
15.00
17.00
19.00
21.00
23.00
25.00
27.00
29.00
31.00



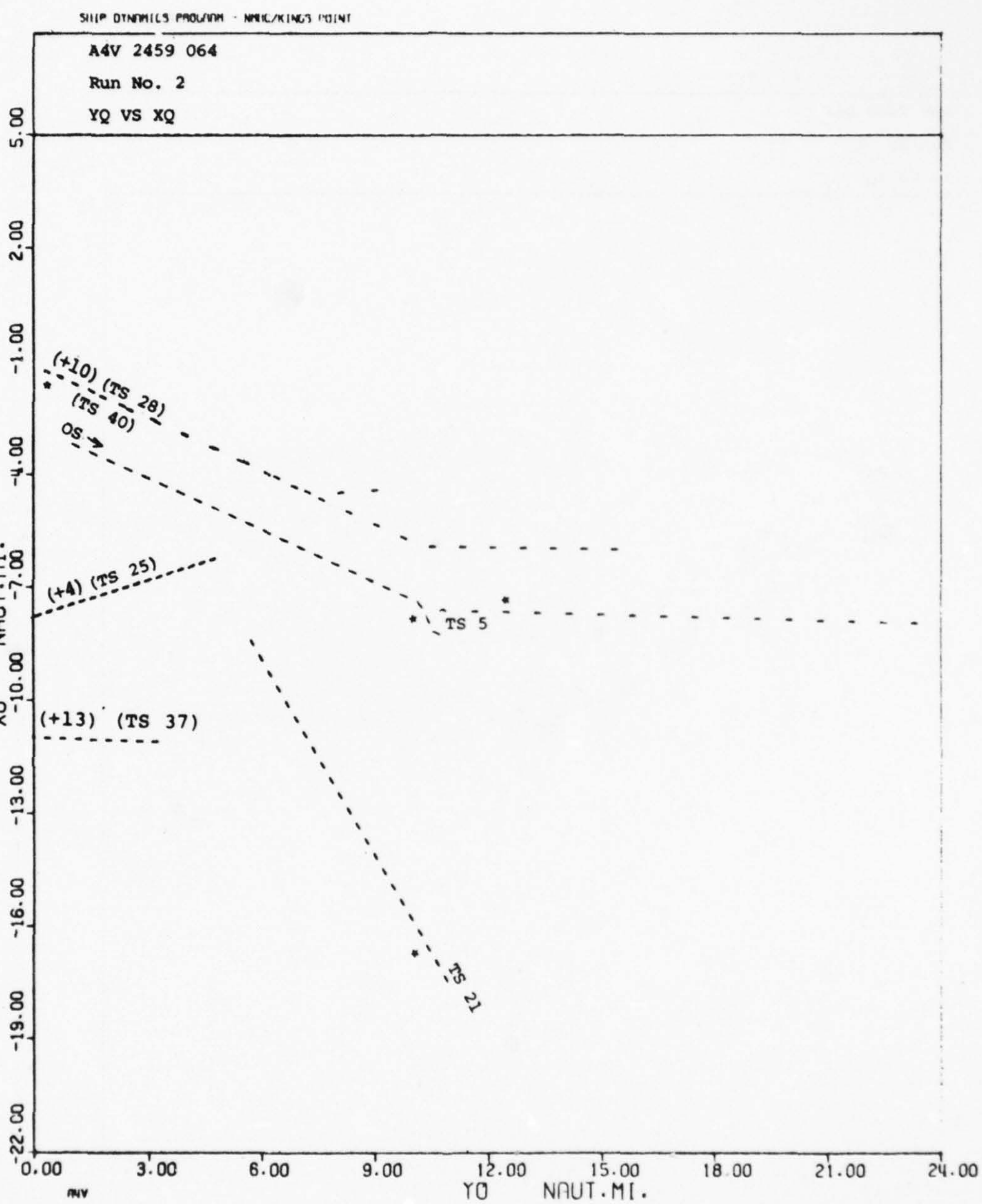
SHIP DYNAMICS PROGRAM - NMDC/KINGS POINT
AIV 2457 064
Run No. 2
YQ VS XQ
(+4) (TS 15)
OS
TS 3
XQ NAUT.MI.
YQ NAUT.MI.
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
-15.00



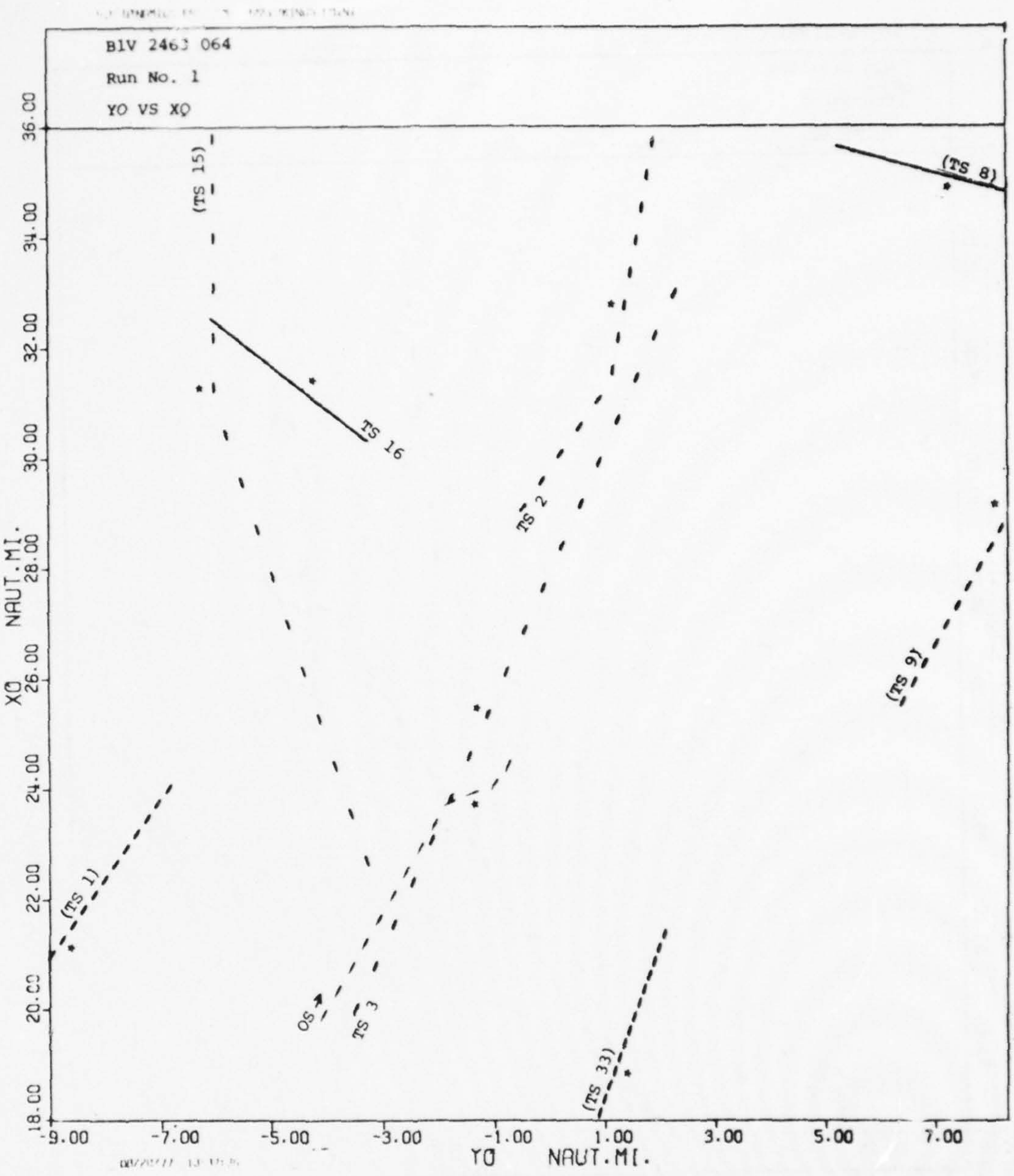
A2V 2458 064
Run No.1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
-23.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
(TS 27)
TS 7
OS
TS 39
(+5) (TS 19)
TS 8
TS 9
TS 1
TS 13
TS 2



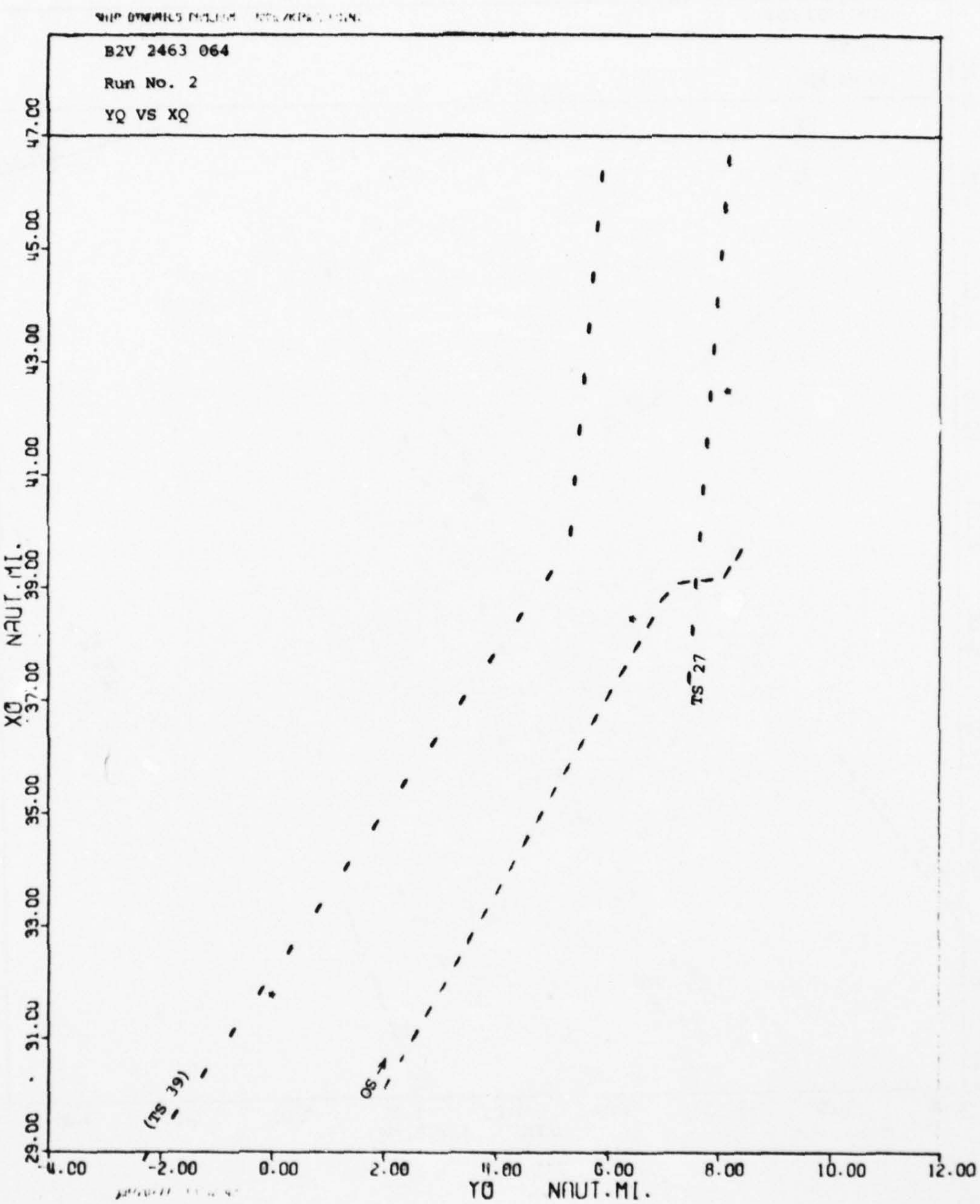
A3V 2459 064
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
(TS 4)
TS 14
OS
TS 16

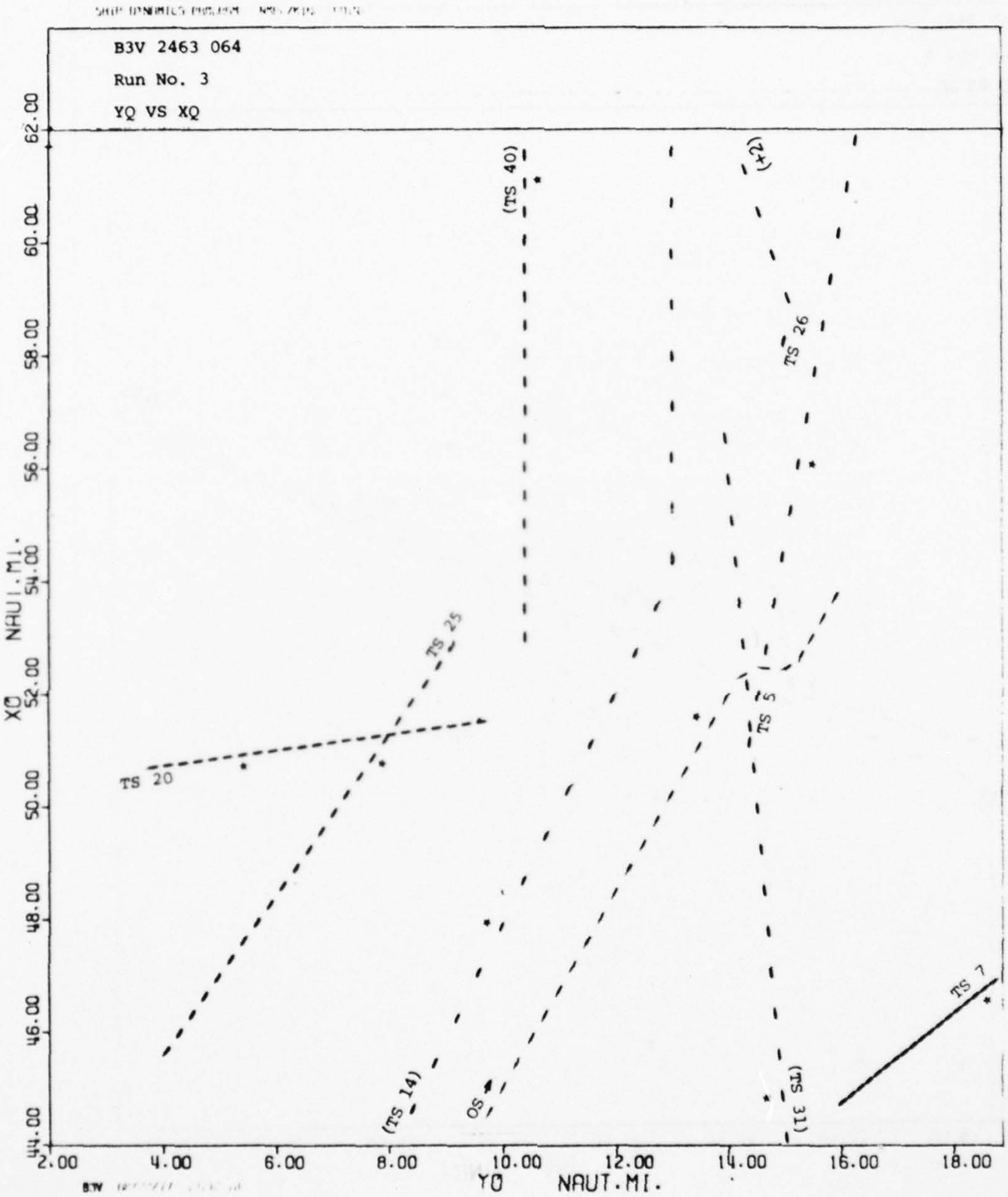


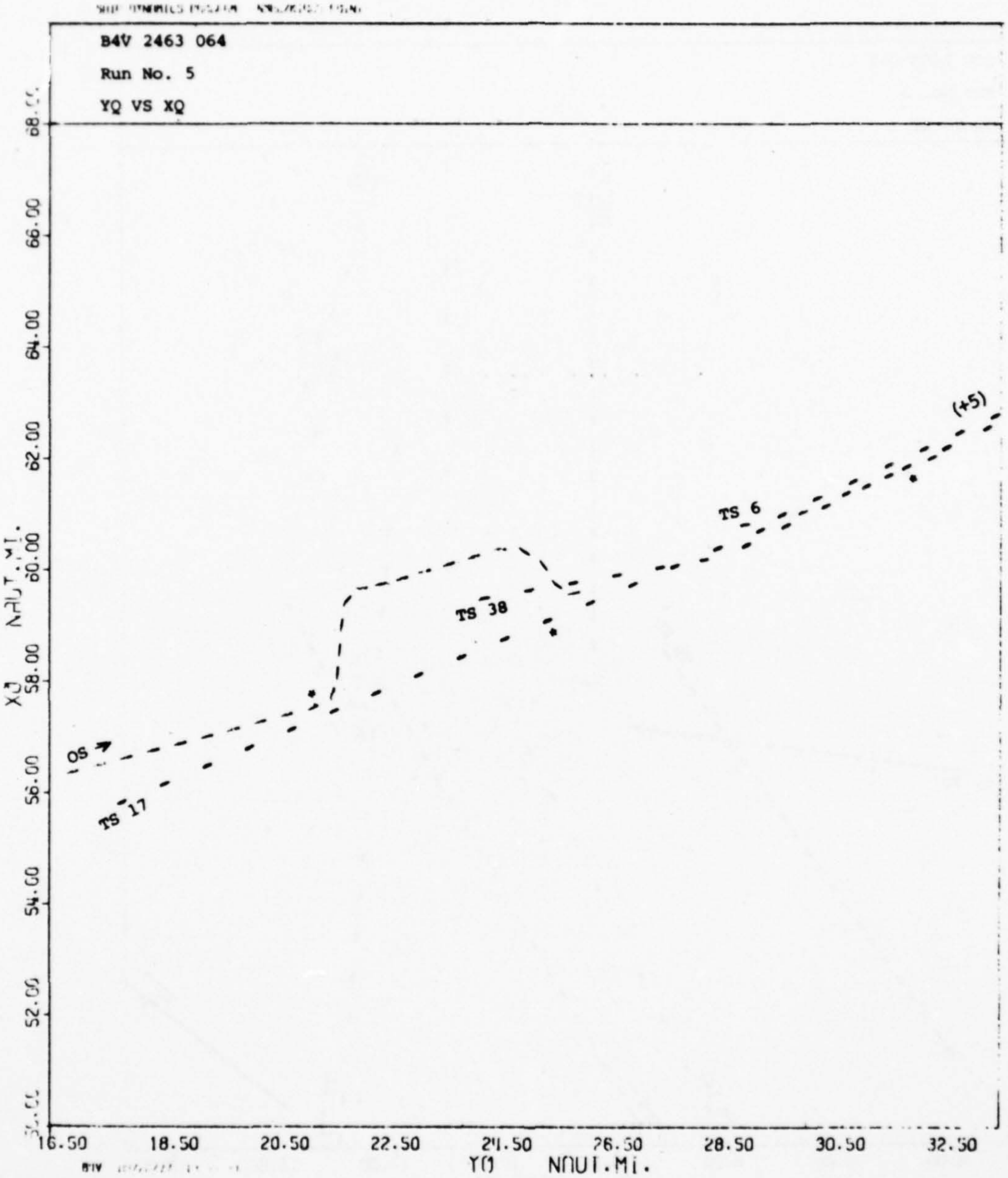
A4V 2459 064
Run No. 2
YQ VS XQ
(+10) (TS 28)
(TS 40)
OS
(+4) (TS 25)
TS 5
(+13) (TS 37)
TS 21
XQ NAUT.MI.
YQ NAUT.MI.
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00

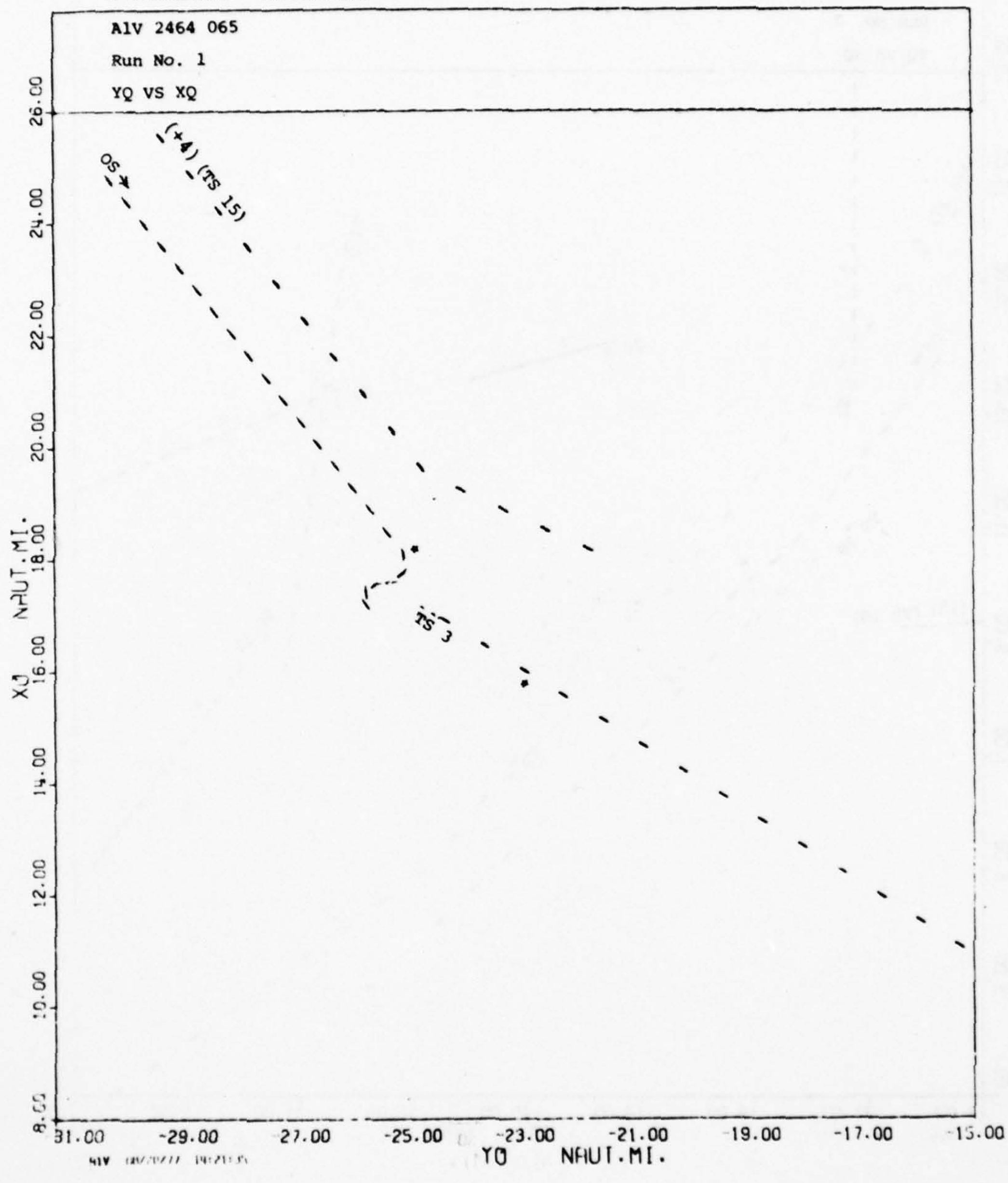


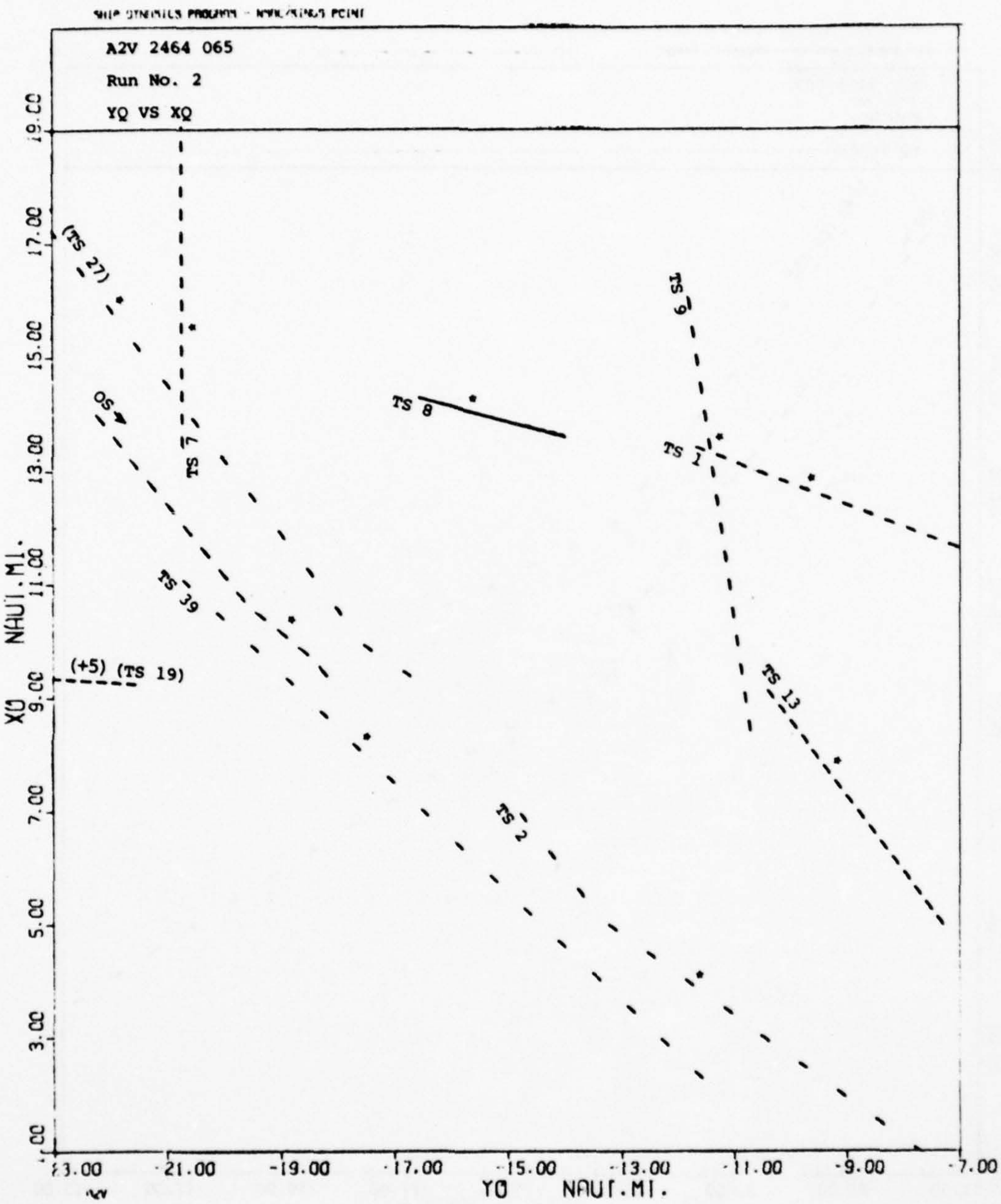
B1V 2463 064
Run No. 1
YO VS XO
XO NAUT.MI.
YO NAUT.MI.
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
-9.00
-7.00
-5.00
-3.00
-1.00
1.00
3.00
5.00
7.00
(TS 15)
TS 16
(TS 8)
TS 2
(TS 9)
(TS 1)
OS
TS 3
(TS 33)

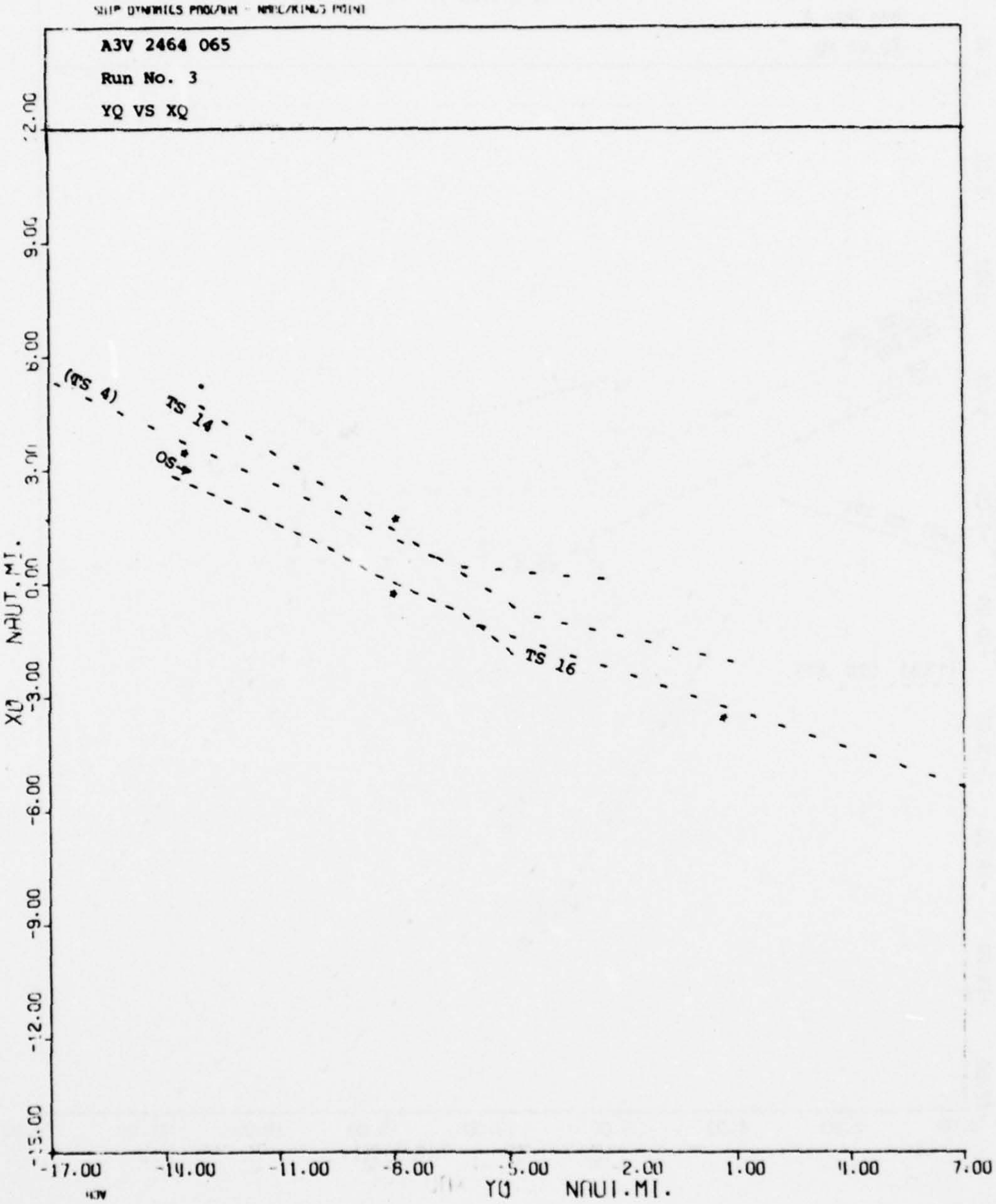

B2V 2463 064
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
47.00
45.00
43.00
41.00
39.00
37.00
35.00
33.00
31.00
29.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
(TS 39)
OS
TS 27


B3V 2463 064
Run No. 3
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
62.00
60.00
58.00
56.00
54.00
52.00
50.00
48.00
46.00
44.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
(TS 40)
(+2)
TS 26
TS 25
TS 20
TS 5
(TS 14)
OS
(TS 31)
TS 7

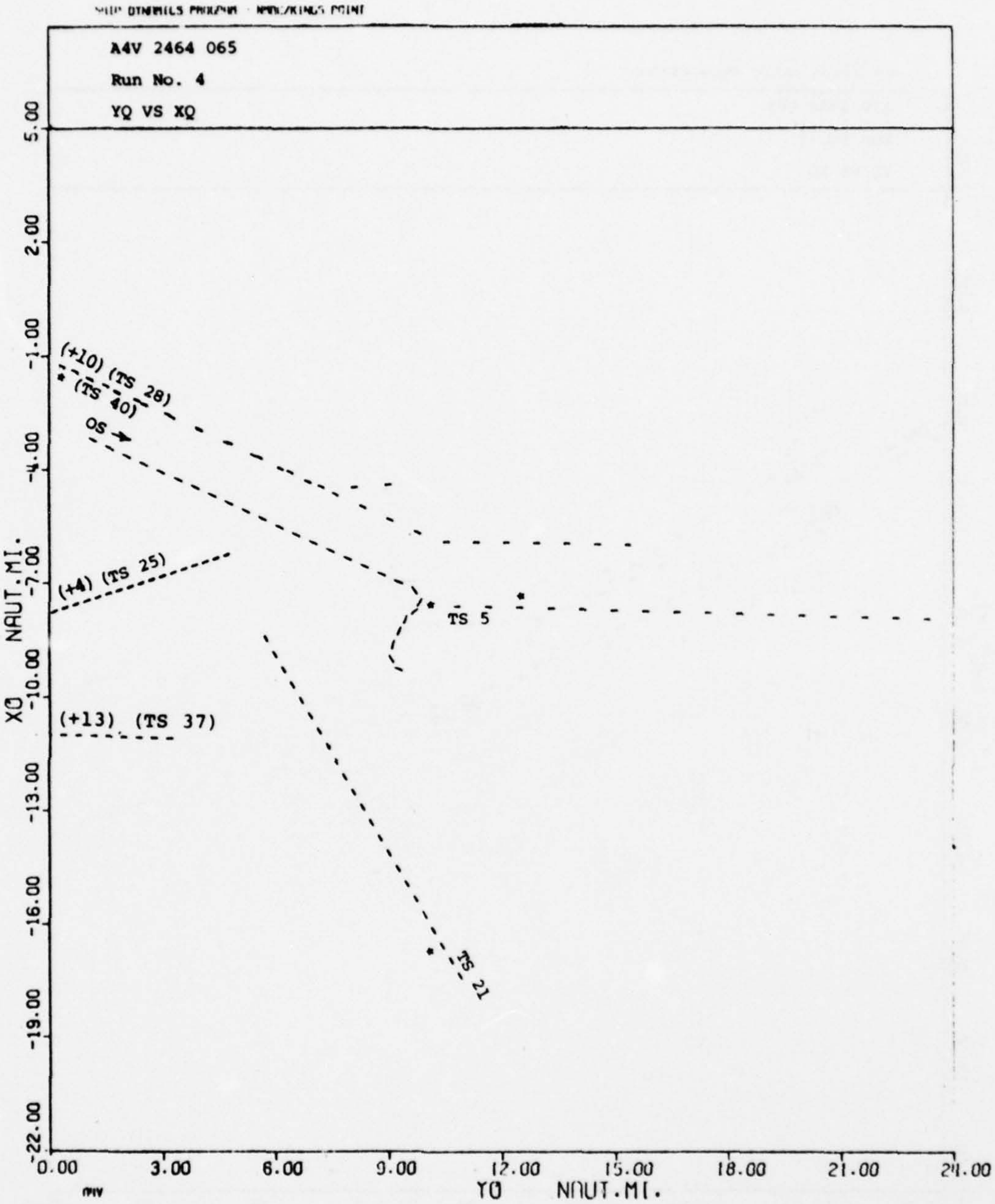

B4V 2463 064
Run No. 5
YQ VS XQ
XQ NAUT.MI.
68.00
66.00
64.00
62.00
60.00
58.00
56.00
54.00
52.00
16.50
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
YQ NAUT.MI.
OS
TS 17
TS 38
TS 6
(+5)


SHIP DYNAMICS PROGRAM NMRC/KINGS POINT
A1V 2464 065
Run No. 1
YQ VS XQ
OS
(+4)
(TS 15)
TS 3
XQ NAUT.MI.
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
-15.00
YQ NAUT.MI.

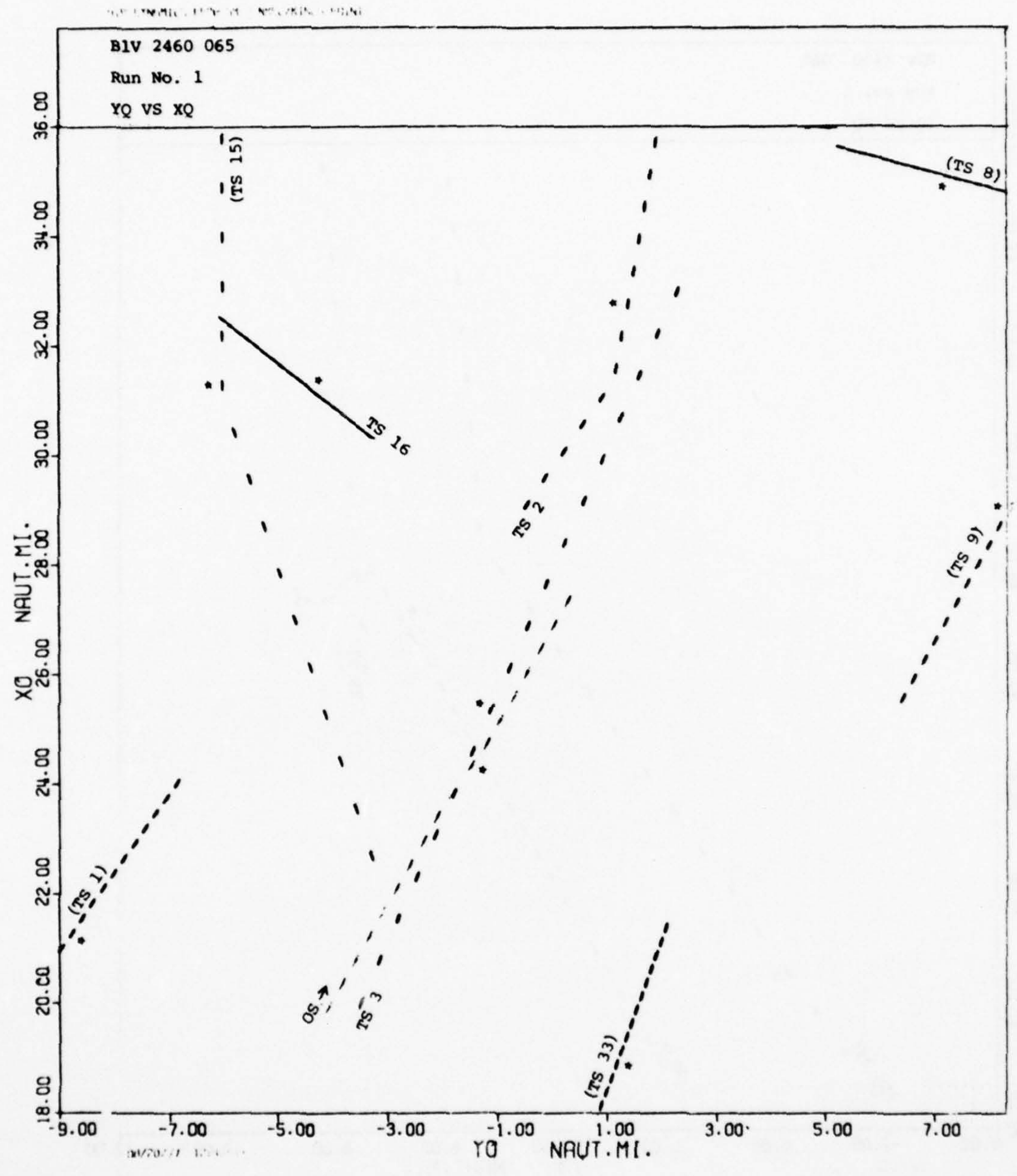

A2V 2464 065
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
-23.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
(TS 27)
TS 7
OS
TS 39
(+5) (TS 19)
TS 8
TS 9
TS 1
TS 13
TS 2

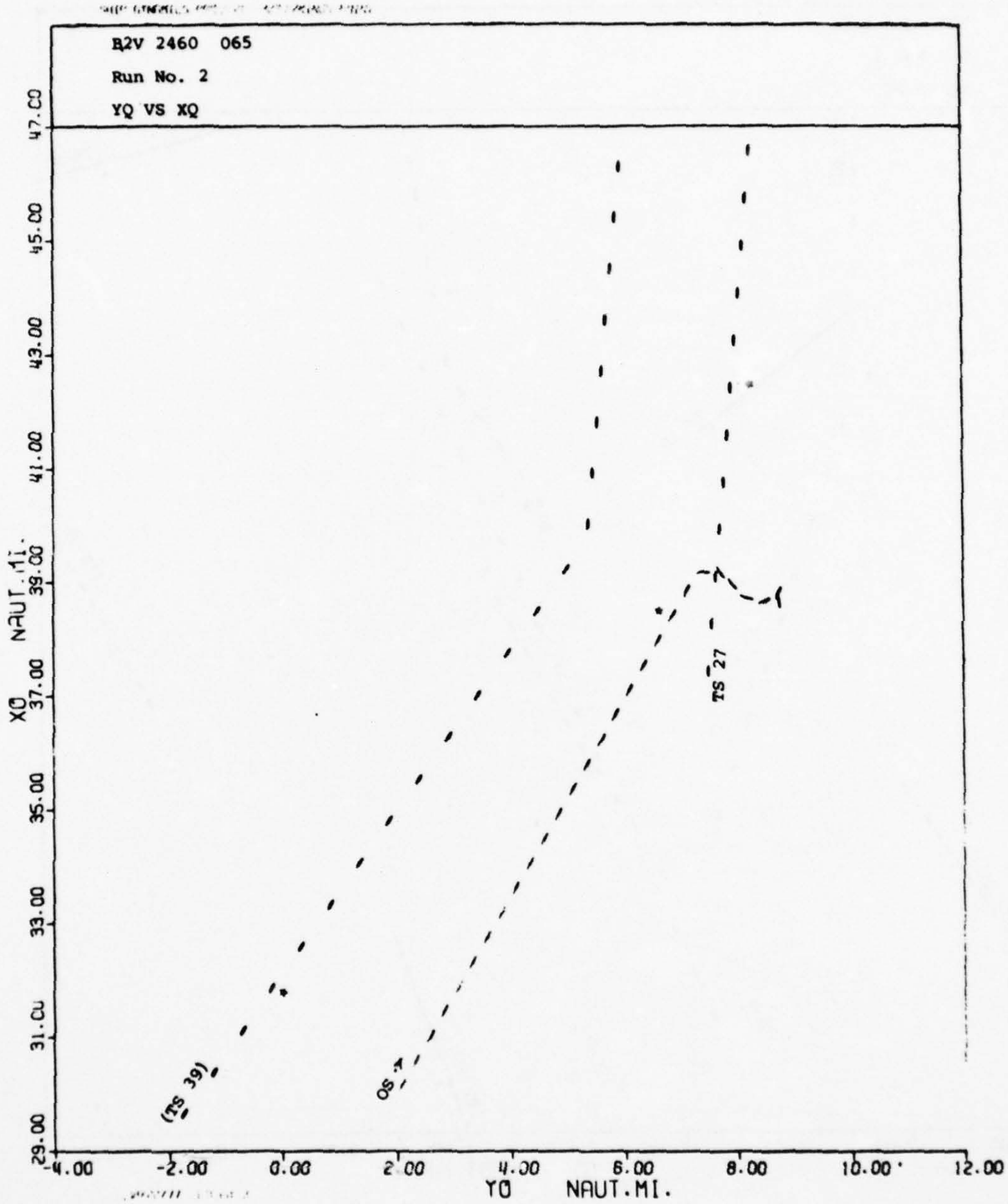


A3V 2464 065
Run No. 3
YQ VS XQ
(TS 4)
TS 14
OS
TS 16
XQ NAUT.MI.
YQ NAUT.MI.
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-17.00
-14.00
-11.00
-8.00
-5.00
2.00
1.00
4.00
7.00

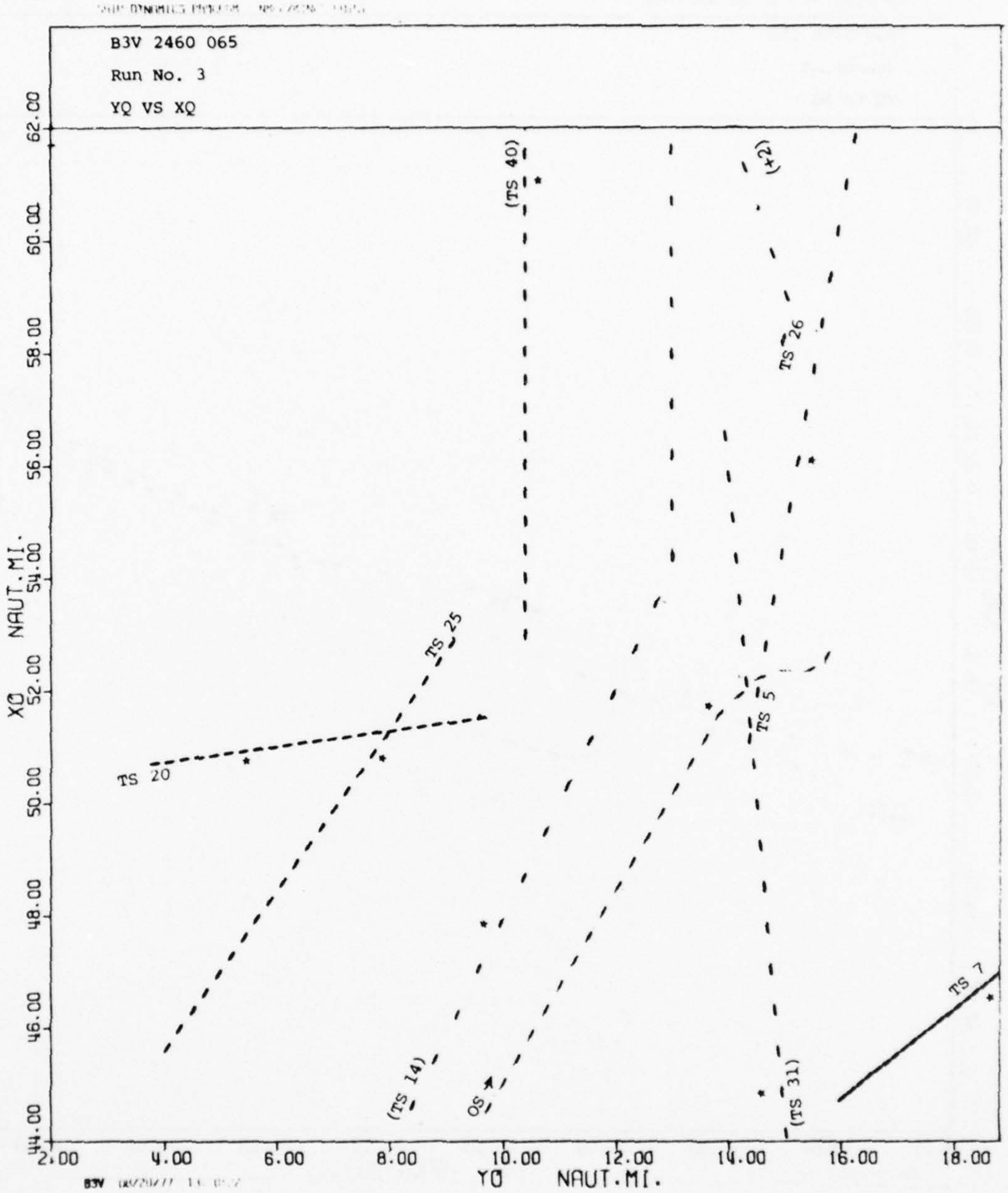


A4V 2464 065
Run No. 4
YQ VS XQ
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
XO NAUT.MI.
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
YO NAUT.MI.
(+10) (TS 28)
(TS 40)
OS
(+4) (TS 25)
TS 5
(+13) (TS 37)
TS 21

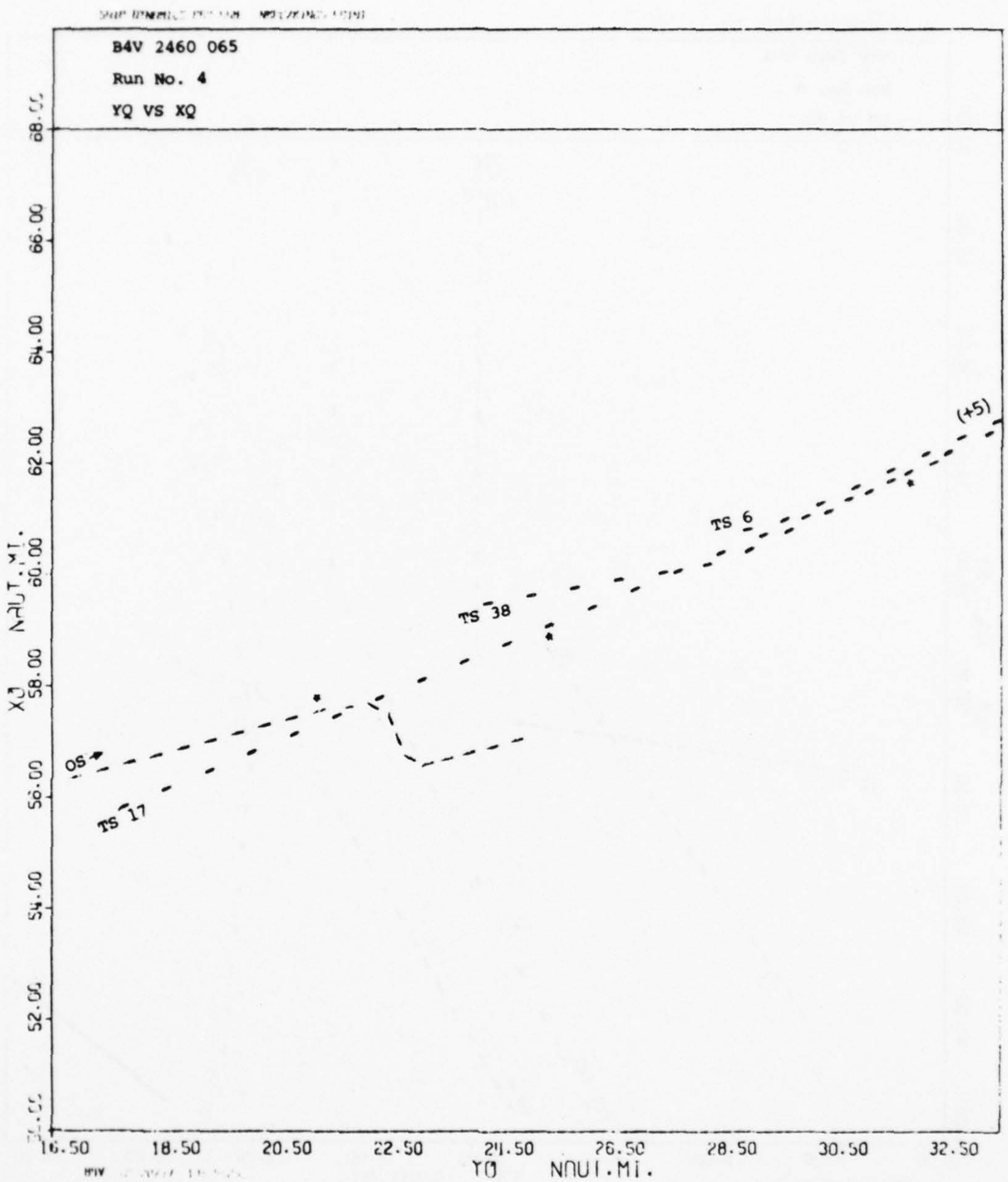

B1V 2460 065
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
18.00
20.00
22.00
24.00
26.00
28.00
30.00
32.00
34.00
36.00
-9.00
-7.00
-5.00
-3.00
-1.00
1.00
3.00
5.00
7.00
(TS 15)
(TS 8)
TS 16
TS 2
(TS 9)
(TS 1)
OS
TS 3
(TS 33)

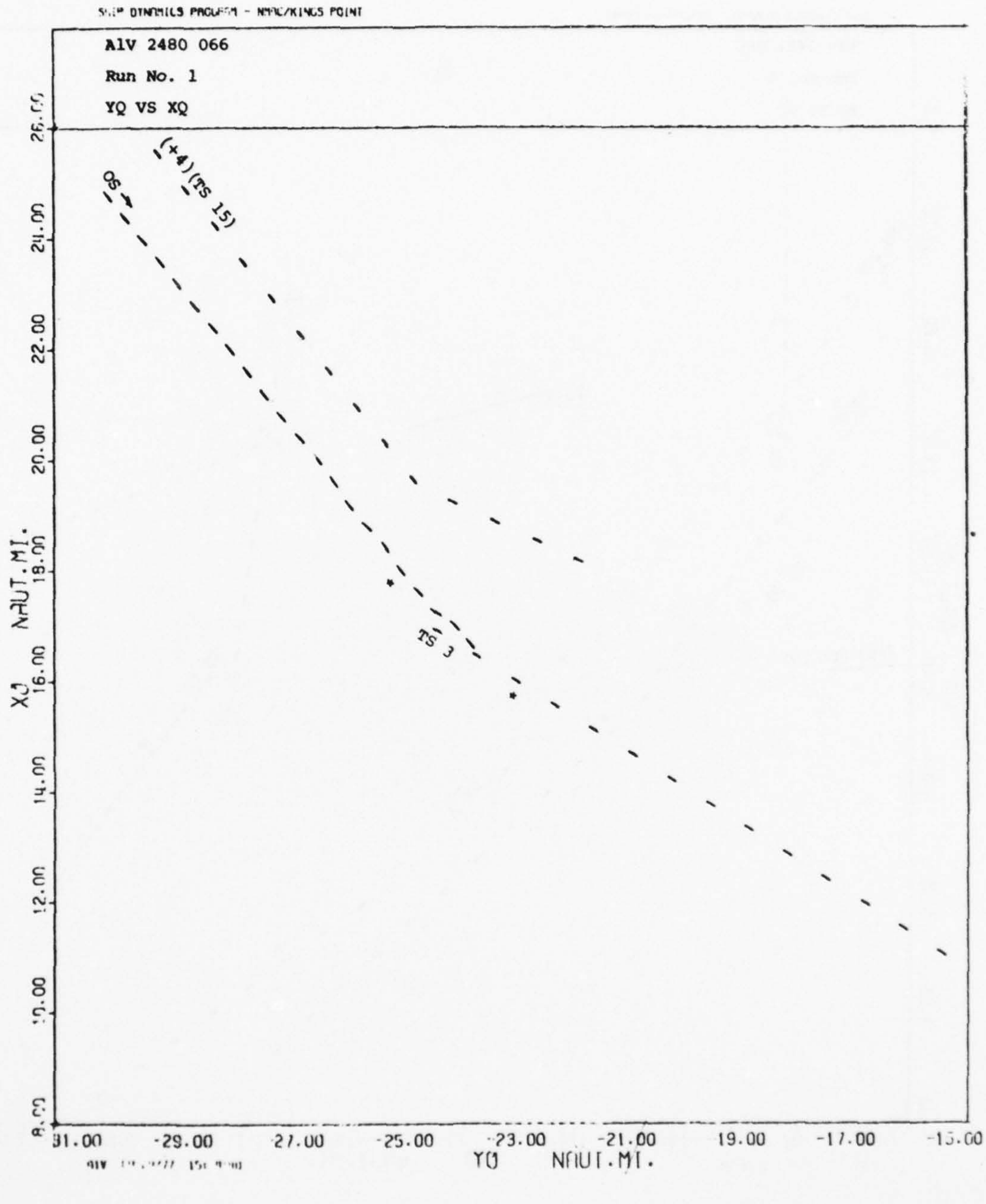


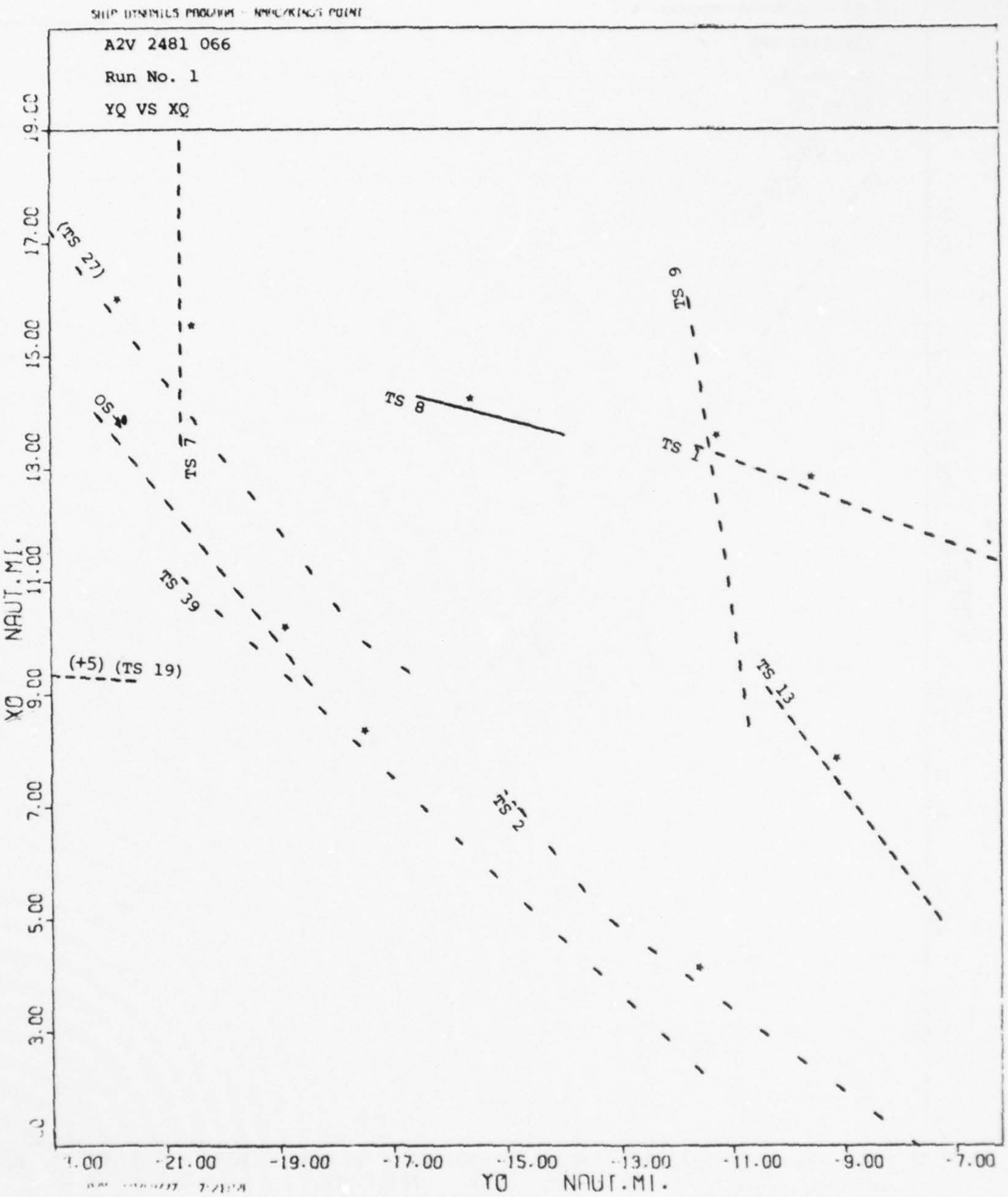
B2V 2460 065
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
TS 39
OS
TS 27
29.00
31.00
33.00
35.00
37.00
39.00
41.00
43.00
45.00
47.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00



B3V 2460 065
Run No. 3
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
62.00
60.00
58.00
56.00
54.00
52.00
50.00
48.00
46.00
44.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
(TS 40)
(+2)
TS 26
TS 25
TS 20
TS 5
TS 7
(TS 14)
OS
(TS 31)


B4V 2460 065
Run No. 4
YQ VS XQ
OS
TS 17
TS 38
TS 6
(+5)
XQ NAUT.MI.
YQ NAUT.MI.


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
AlV 2480 066
Run No. 1
YQ VS XQ
OS
(+4)(TS 15)
TS 3
XQ NAUT.MI.
YQ NAUT.MI.
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
31.00
-29.00
-27.00
-25.00
-23.00
-21.00
19.00
-17.00
-15.00



A2V 2481 066
Run No. 1
YQ VS XQ
(TS 27)
TS 7
OS
TS 8
TS 9
TS 1
TS 39
(+5) (TS 19)
TS 13
TS 2
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
XQ NAUT.MI.
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
YQ NAUT.MI.

AD-A071 056 NATIONAL MARITIME RESEARCH CENTER KINGS POINT NY F/G 17/7
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UNCLASSIFIED CAORF-103 USCG-D-25-79 NL

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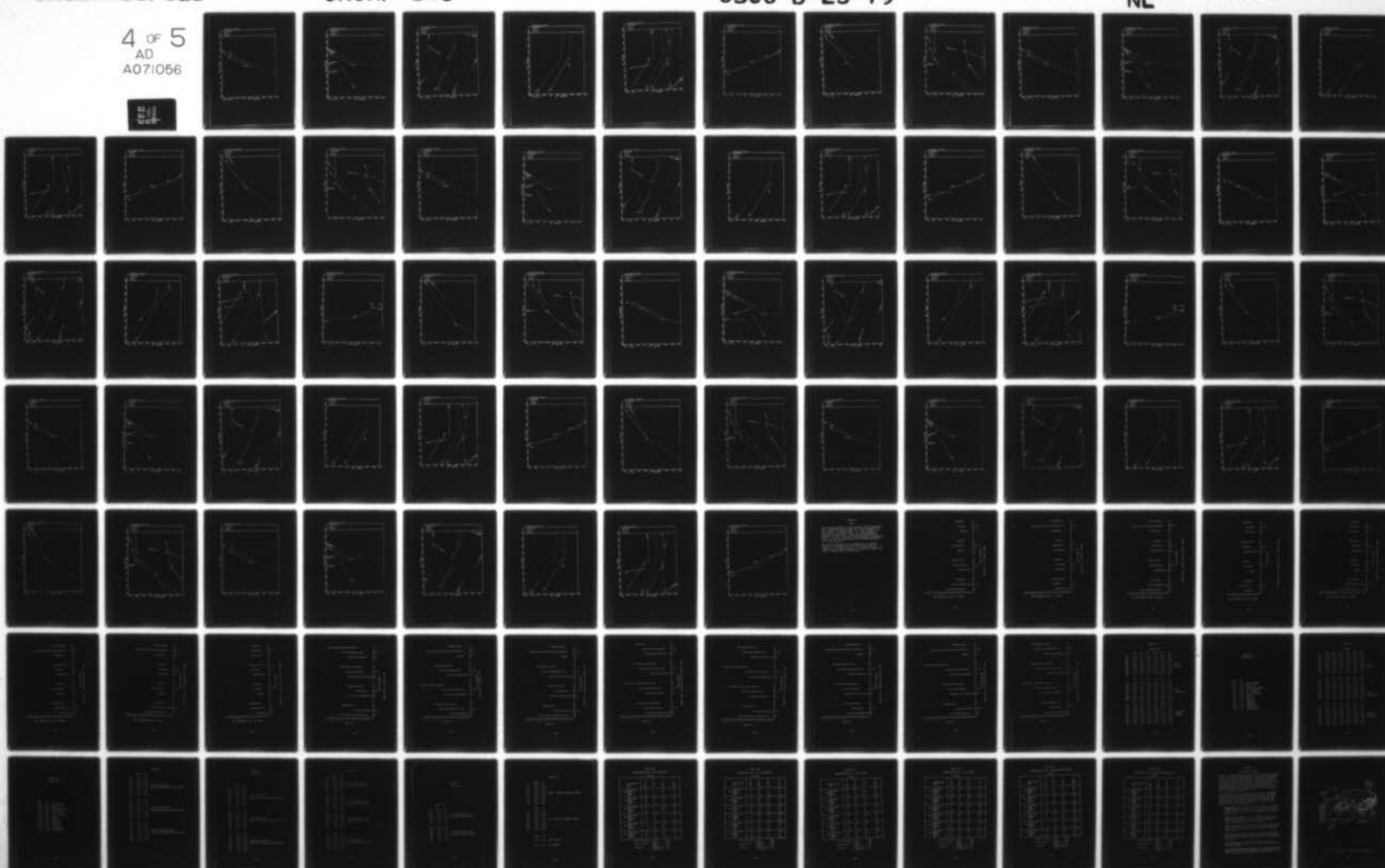
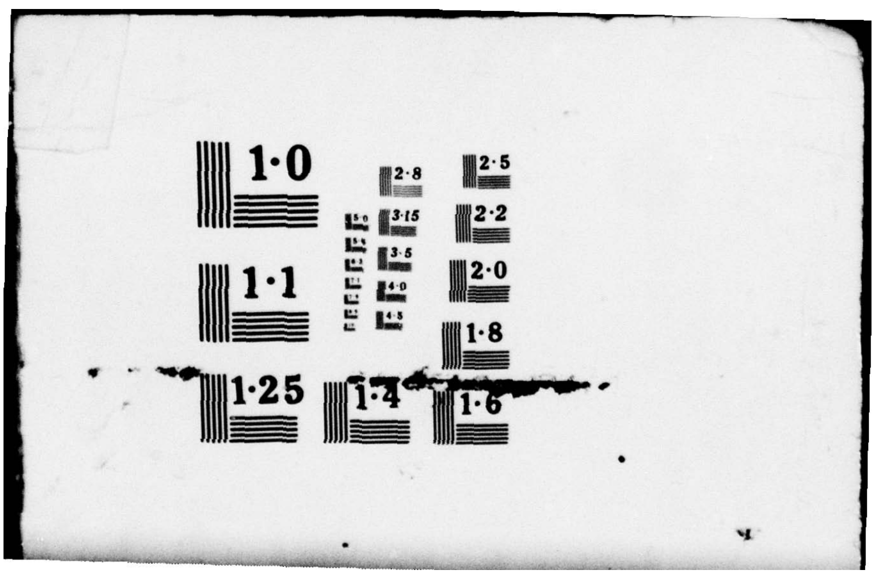
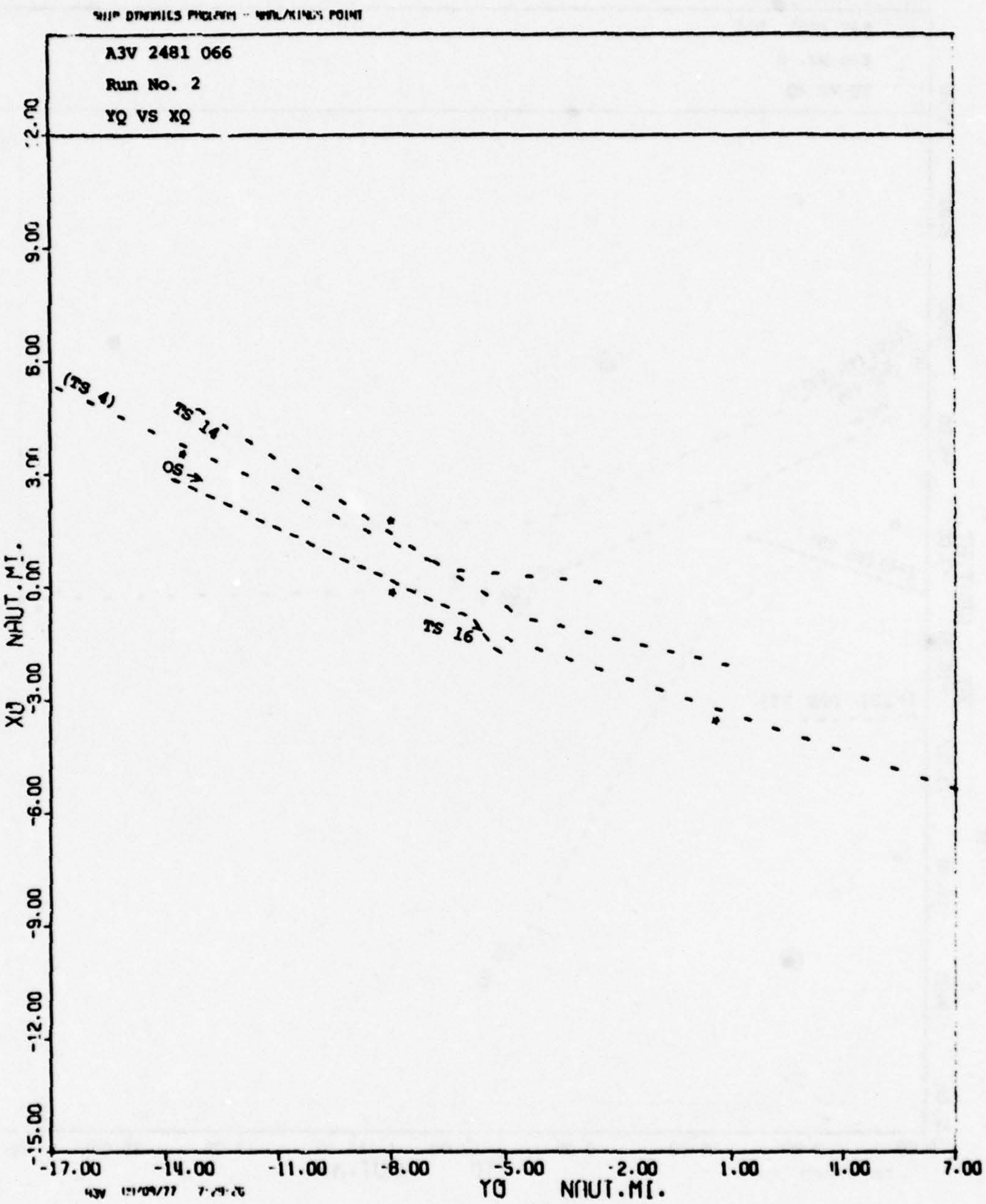
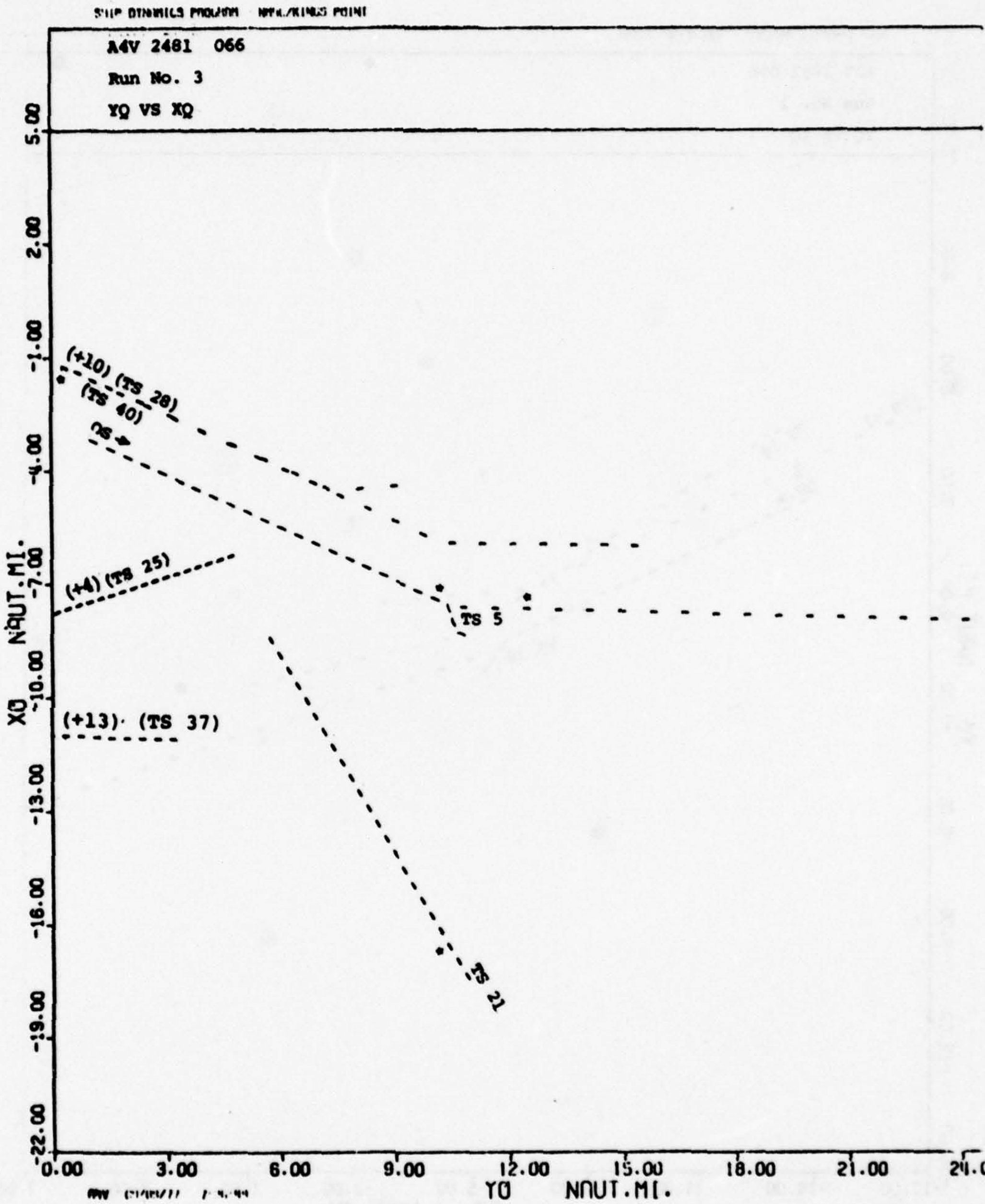
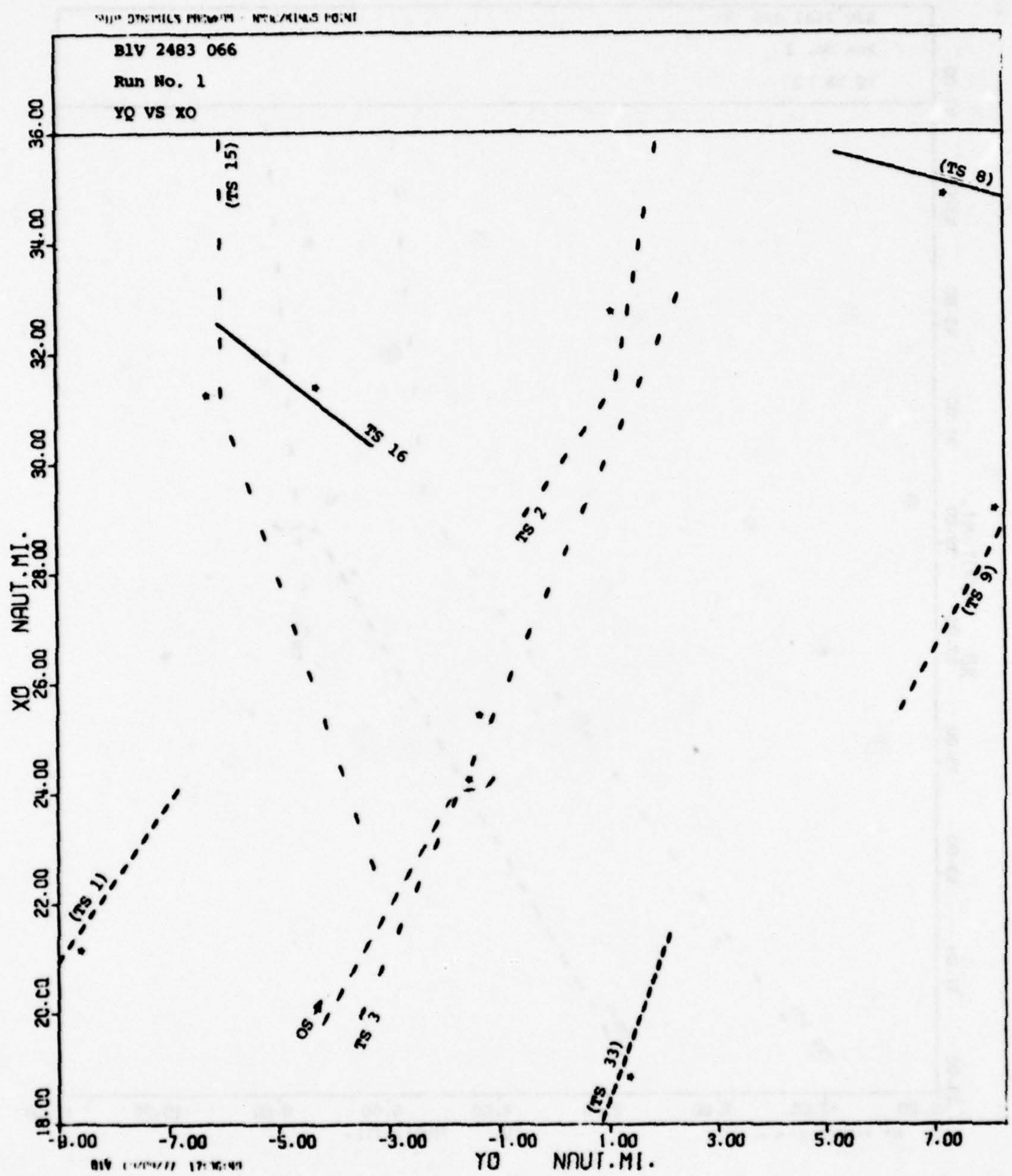
A071056



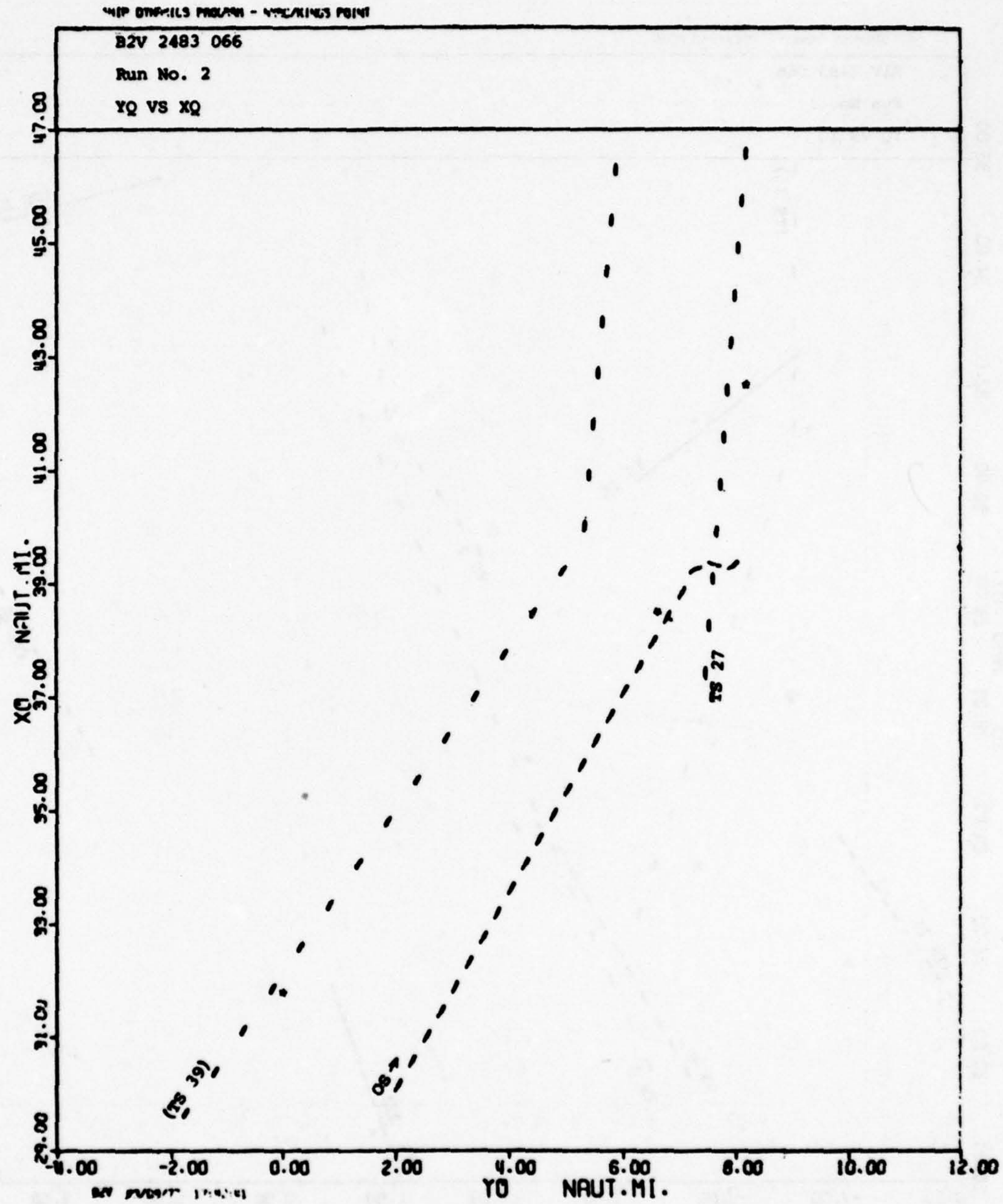

1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
1·1
4·5
1·8
1·25
1·4
1·6


A3V 2481 066
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
TS 4
TS 14
OS
TS 16
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-17.00
-14.00
-11.00
-8.00
-5.00
-2.00
1.00
4.00
7.00

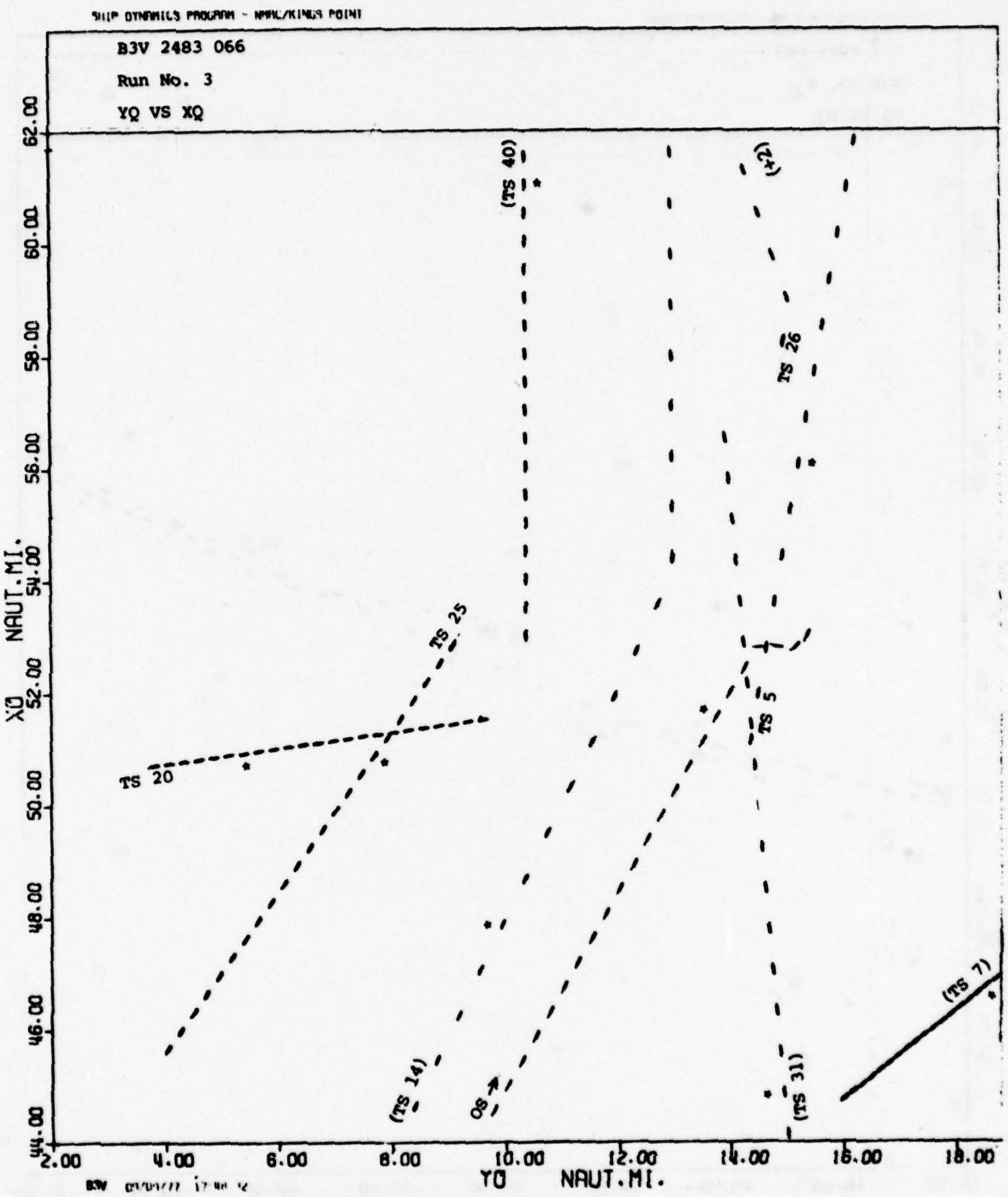

A4V 2481 066
Run No. 3
YQ VS XQ
(+10) (TS 28)
(TS 40)
OS
(+4) (TS 25)
TS 5
(+13) (TS 37)
TS 21
XQ NAUT.MI.
YQ NAUT.MI.
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00



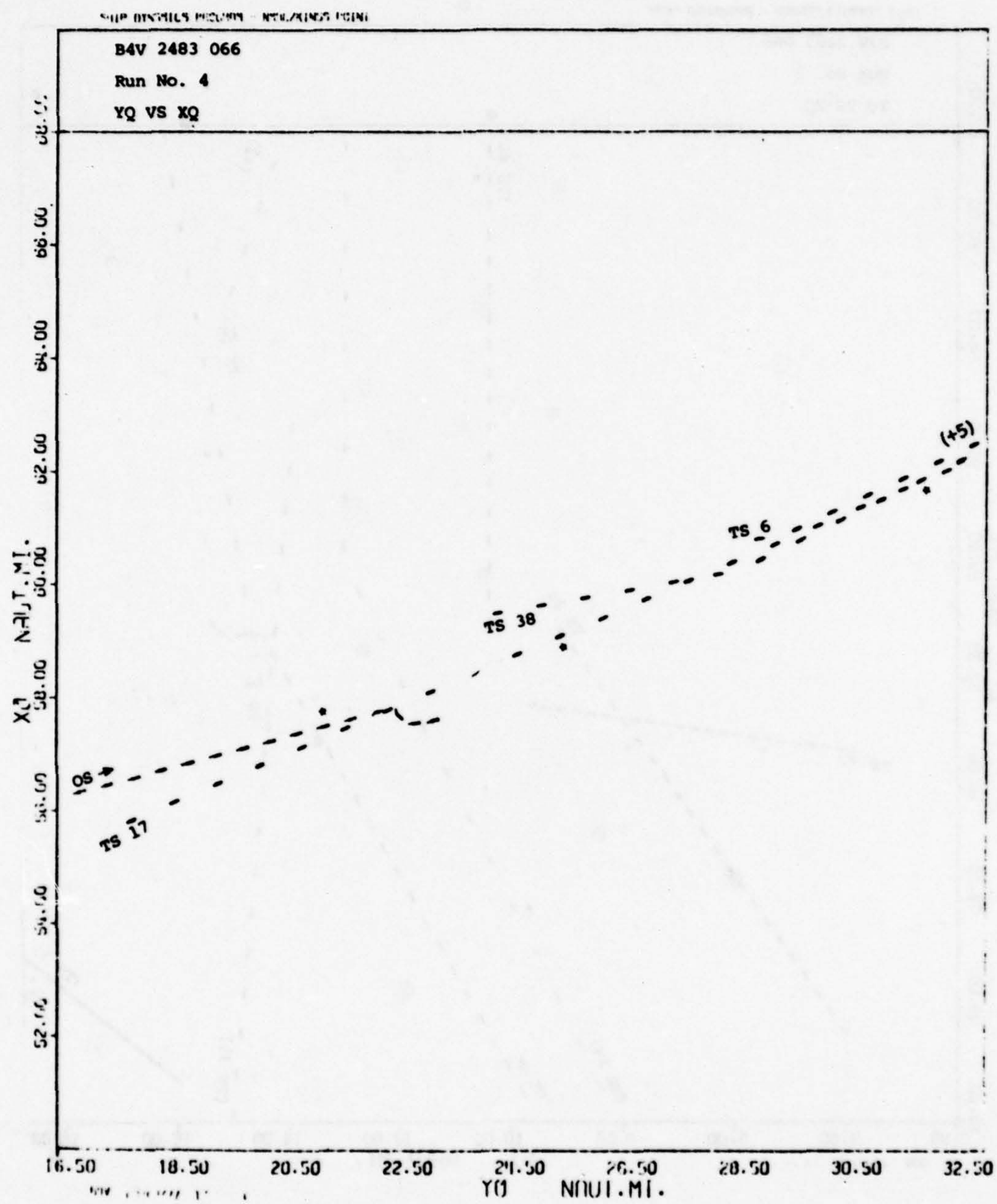
B1V 2483 066
Run No. 1
YO VS XO
(TS 15)
(TS 8)
TS 16
TS 2
(TS 9)
(TS 1)
OS
TS 3
(TS 33)
XO NAUT.MI.
YO NAUT.MI.



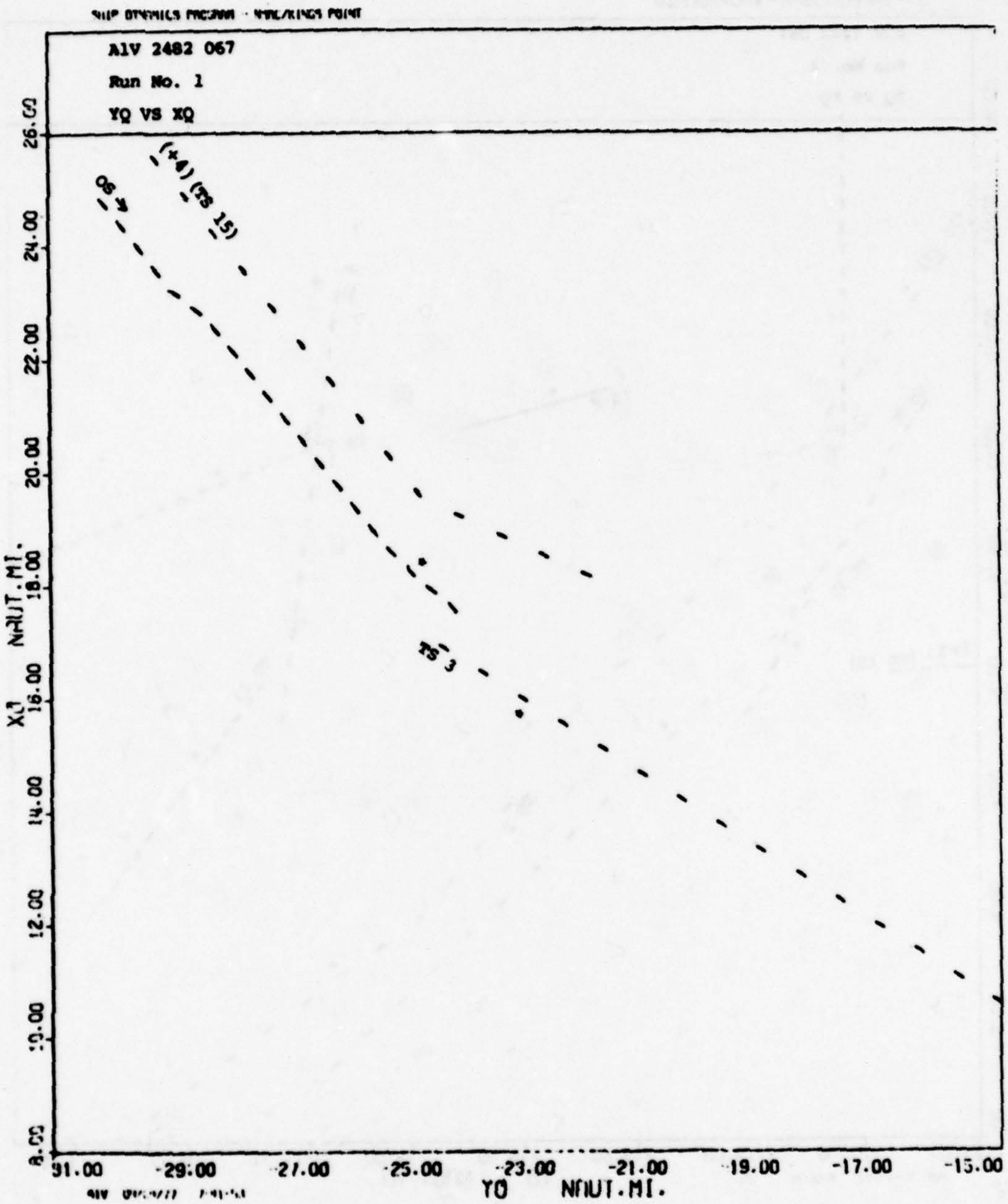
B2V 2483 066
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
TS 39
TS 27
OS

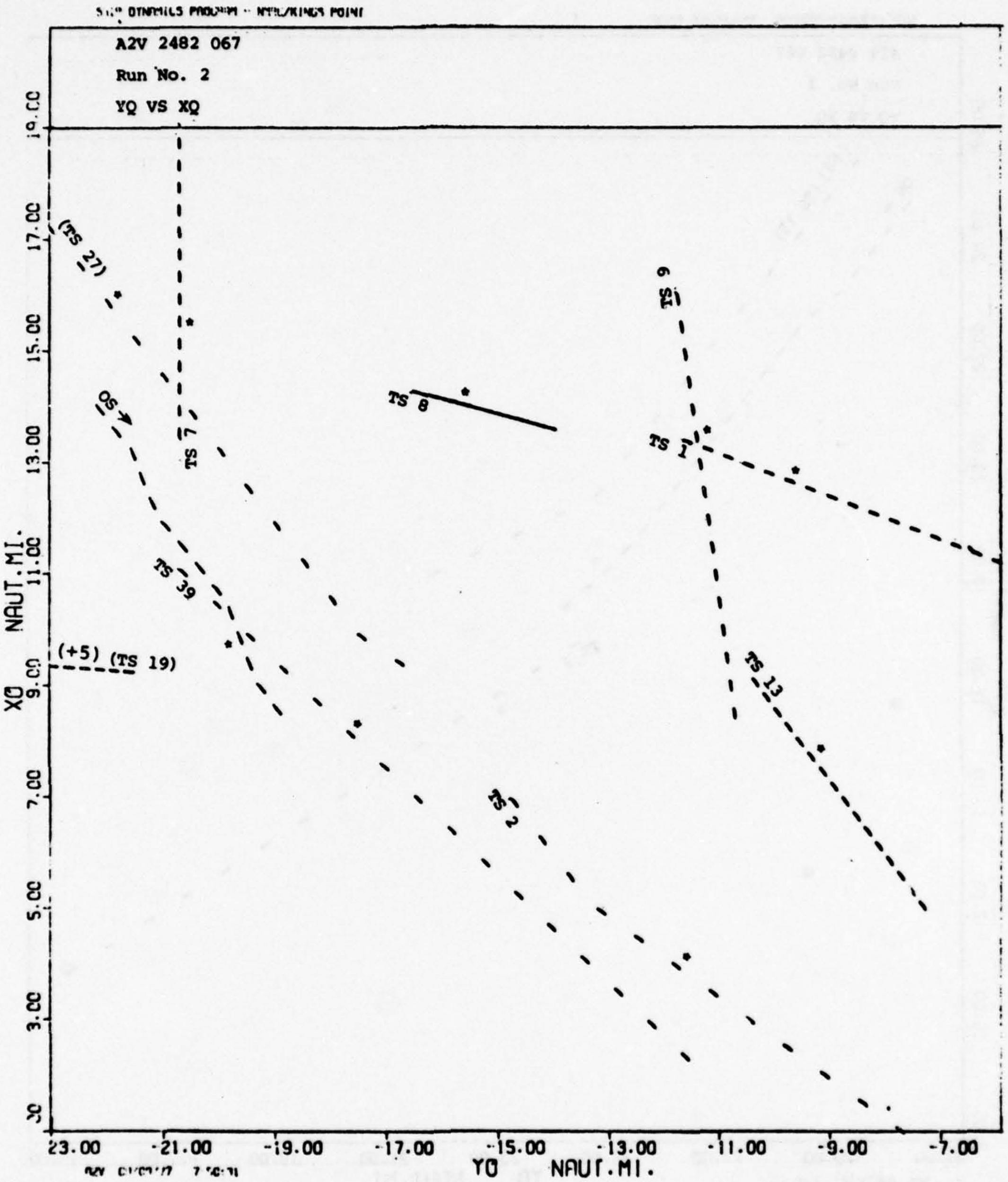


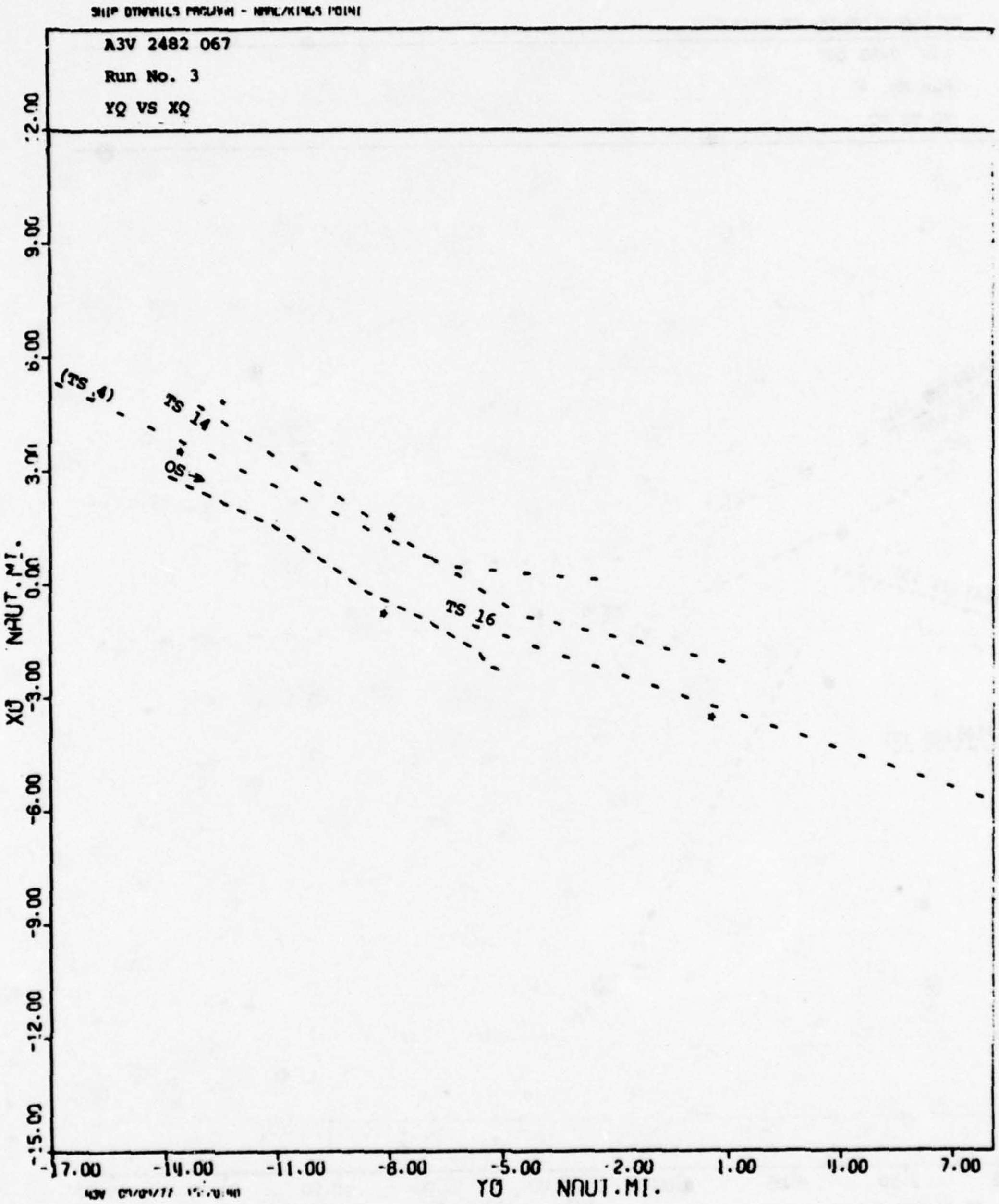
SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B3V 2483 066
Run No. 3
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
TS 40
TS 26
TS 25
TS 20
TS 5
TS 14
OS
TS 31
TS 7



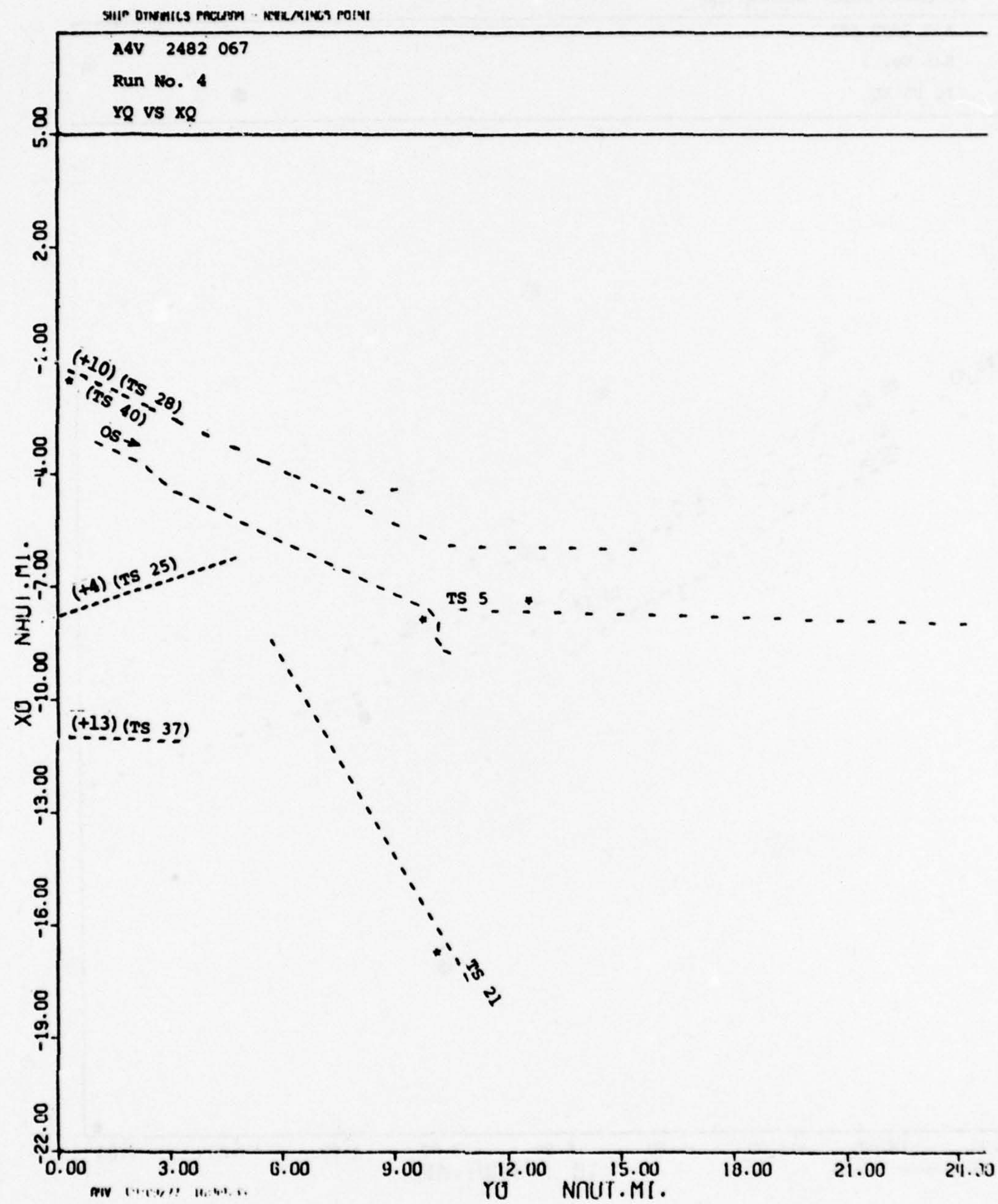
B4V 2483 066
Run No. 4
YQ VS XQ
OS
TS 17
TS 38
TS 6
(+5)
16.50
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
YQ NAUT.MI.
XQ NAUT.MI.
56.00
58.00
60.00
62.00
64.00
66.00


SHIP DYNAMICS PROGRAM - MARAD/KINGS POINT
A1V 2482 067
Run No. 1
YQ VS XQ
OS
(+4) (TS 15)
TS 3
XQ NAUT.MI.
YQ NAUT.MI.
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
-15.00

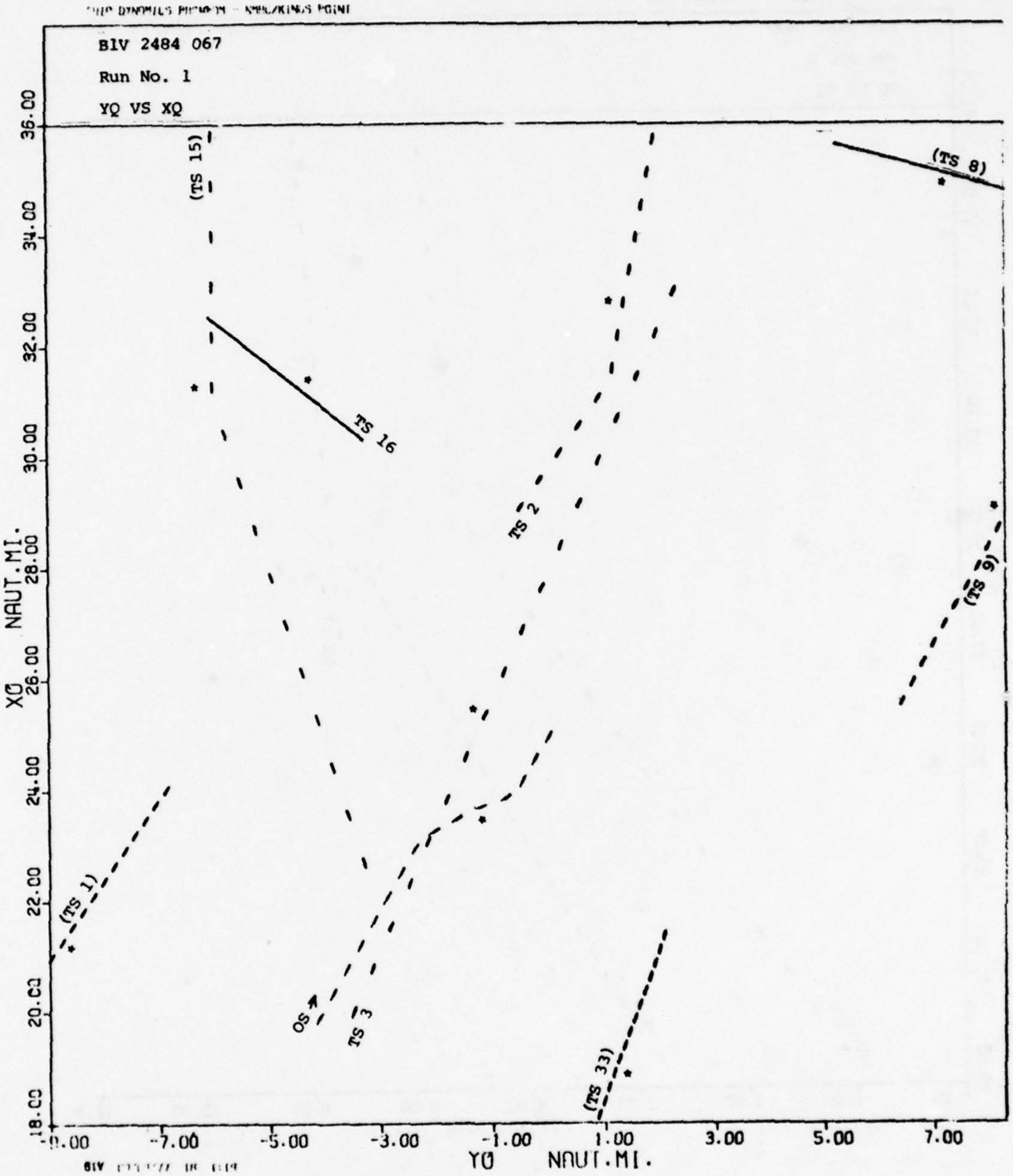

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A2V 2482 067
Run No. 2
YO VS XO
XO NAUT.MI.
YO NAUT.MI.
(TS 27)
TS 7
OS
TS 8
TS 9
TS 1
TS 39
(+5) (TS 19)
TS 13
TS 2
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
-23.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00



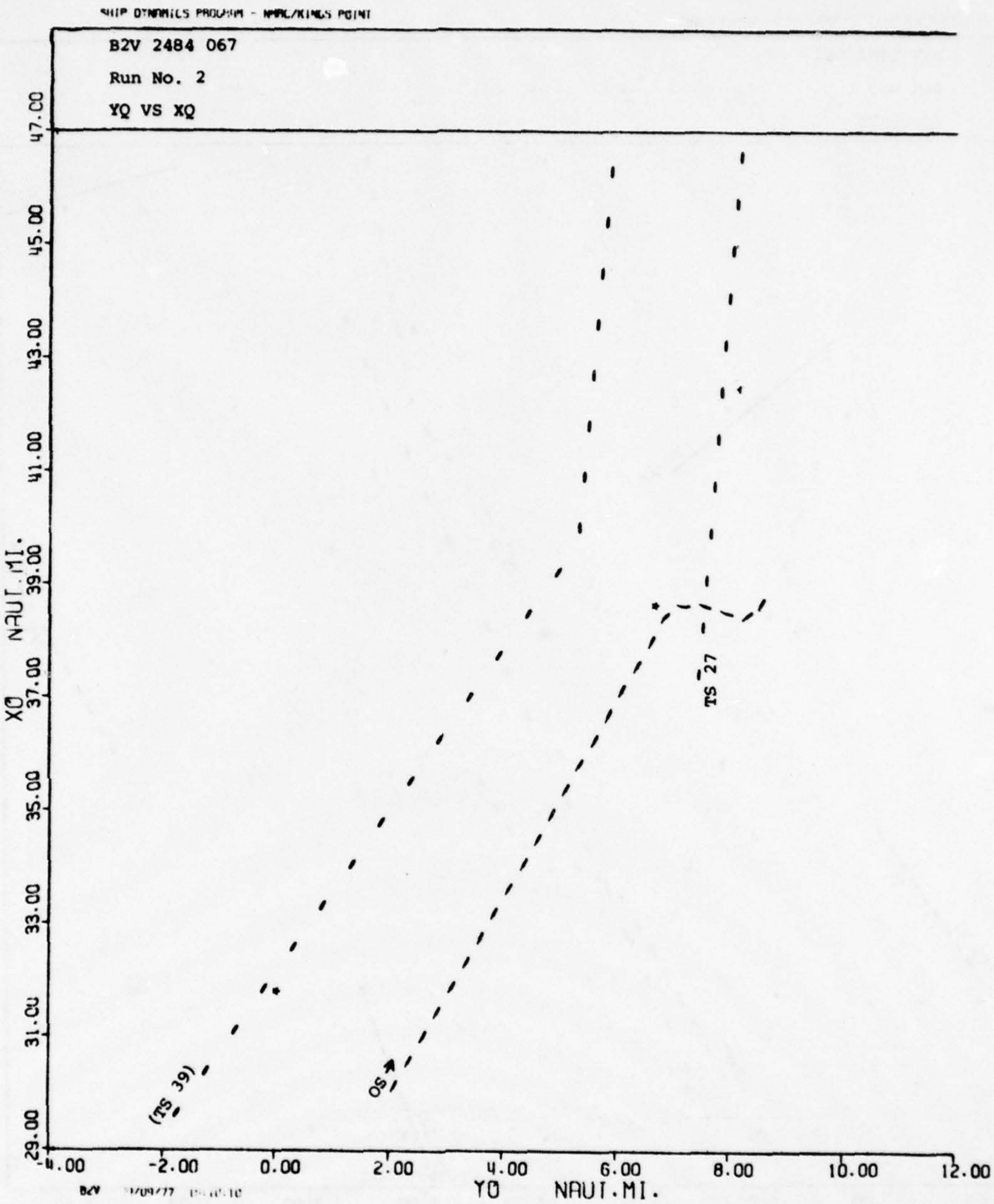
A3V 2482 067
Run No. 3
YQ VS XQ
(TS 4)
TS 14
OS
TS 16
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
XO NAUT.MI.
-17.00
-14.00
-11.00
-8.00
-5.00
-2.00
1.00
4.00
7.00
YO NAUT.MI.

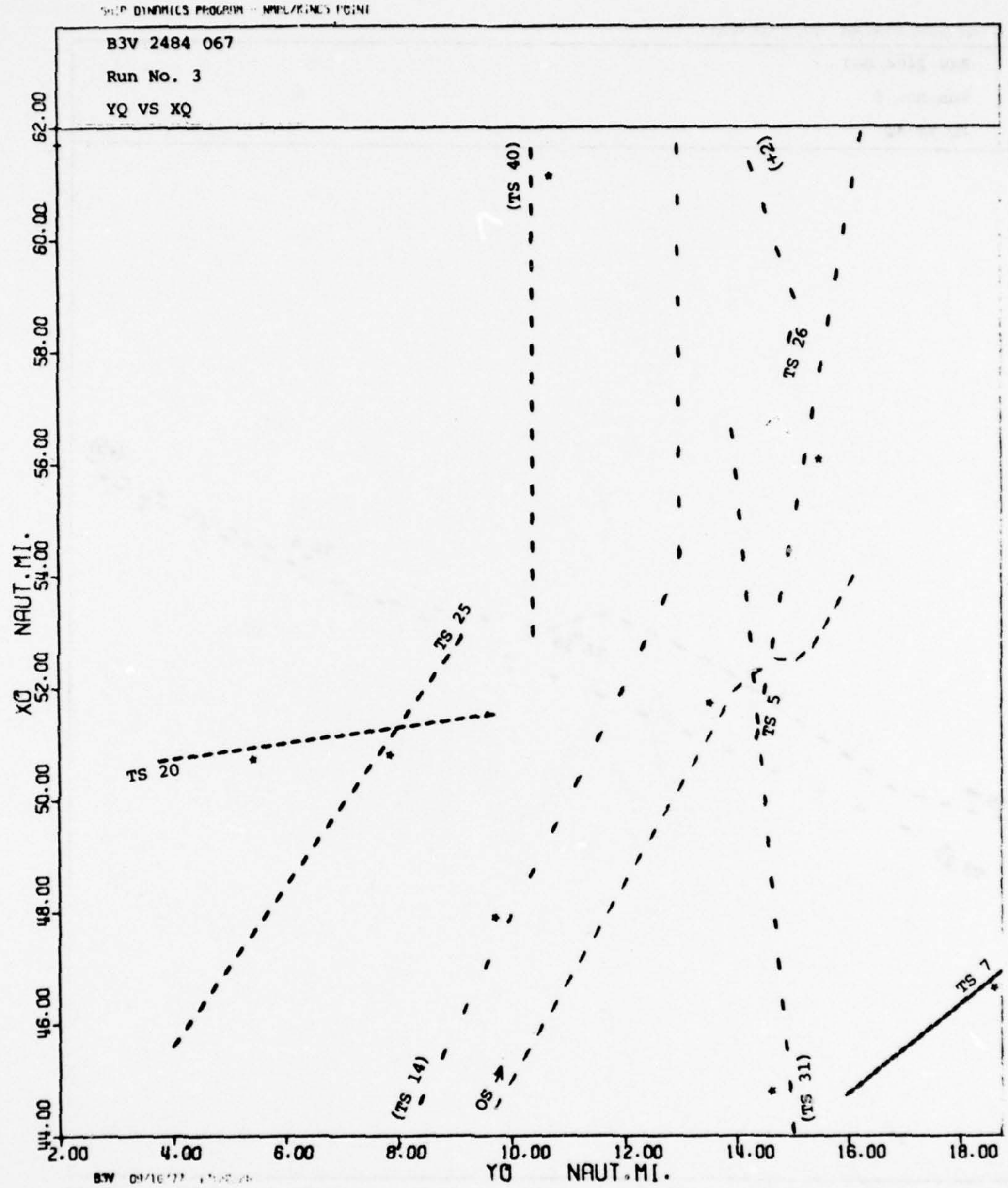


A4V 2482 067
Run No. 4
YQ VS XQ
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
XQ NAUT.MI.
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
YQ NAUT.MI.
(+10) (TS 28)
(TS 40)
OS
(+4) (TS 25)
TS 5
(+13) (TS 37)
TS 21

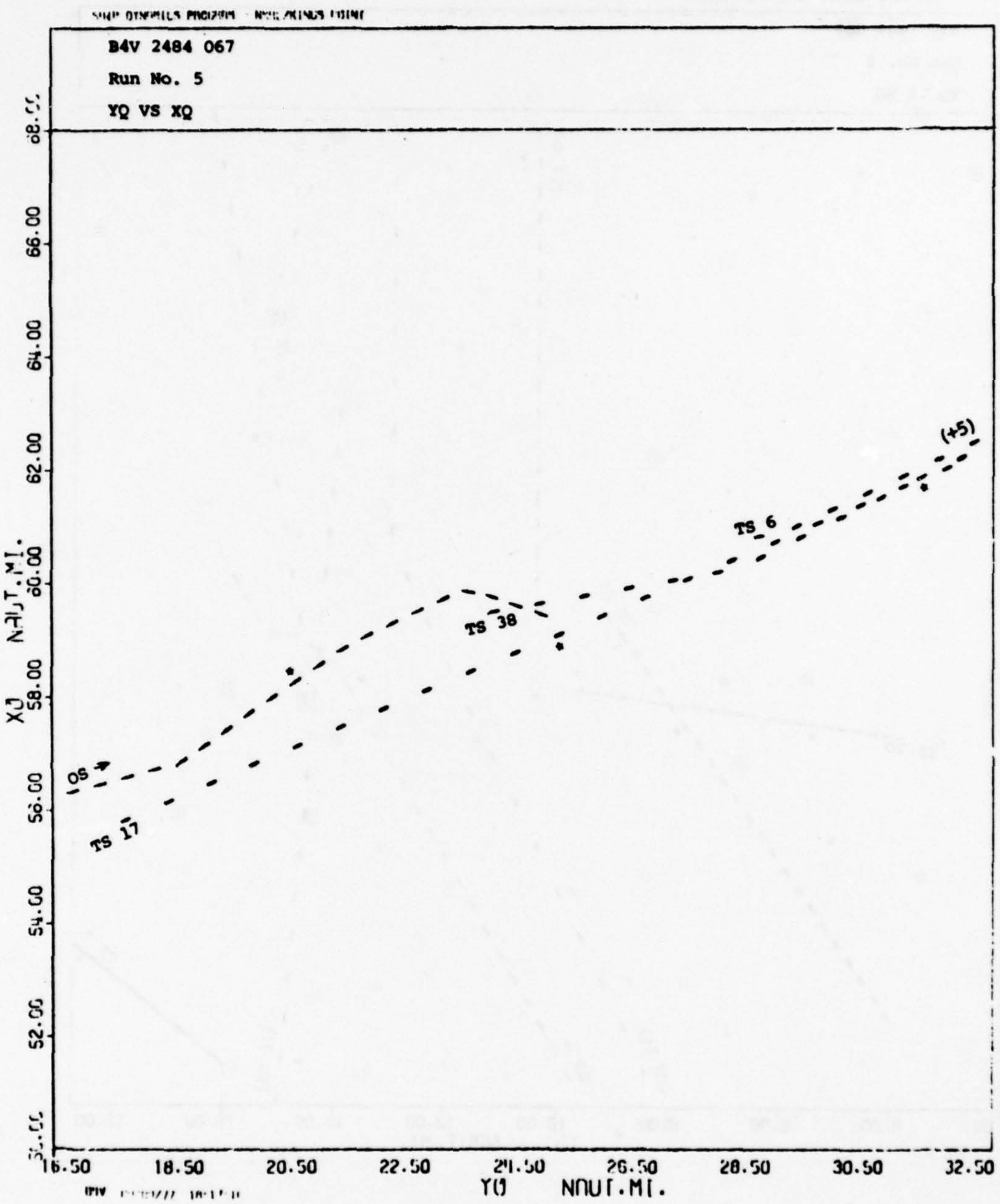


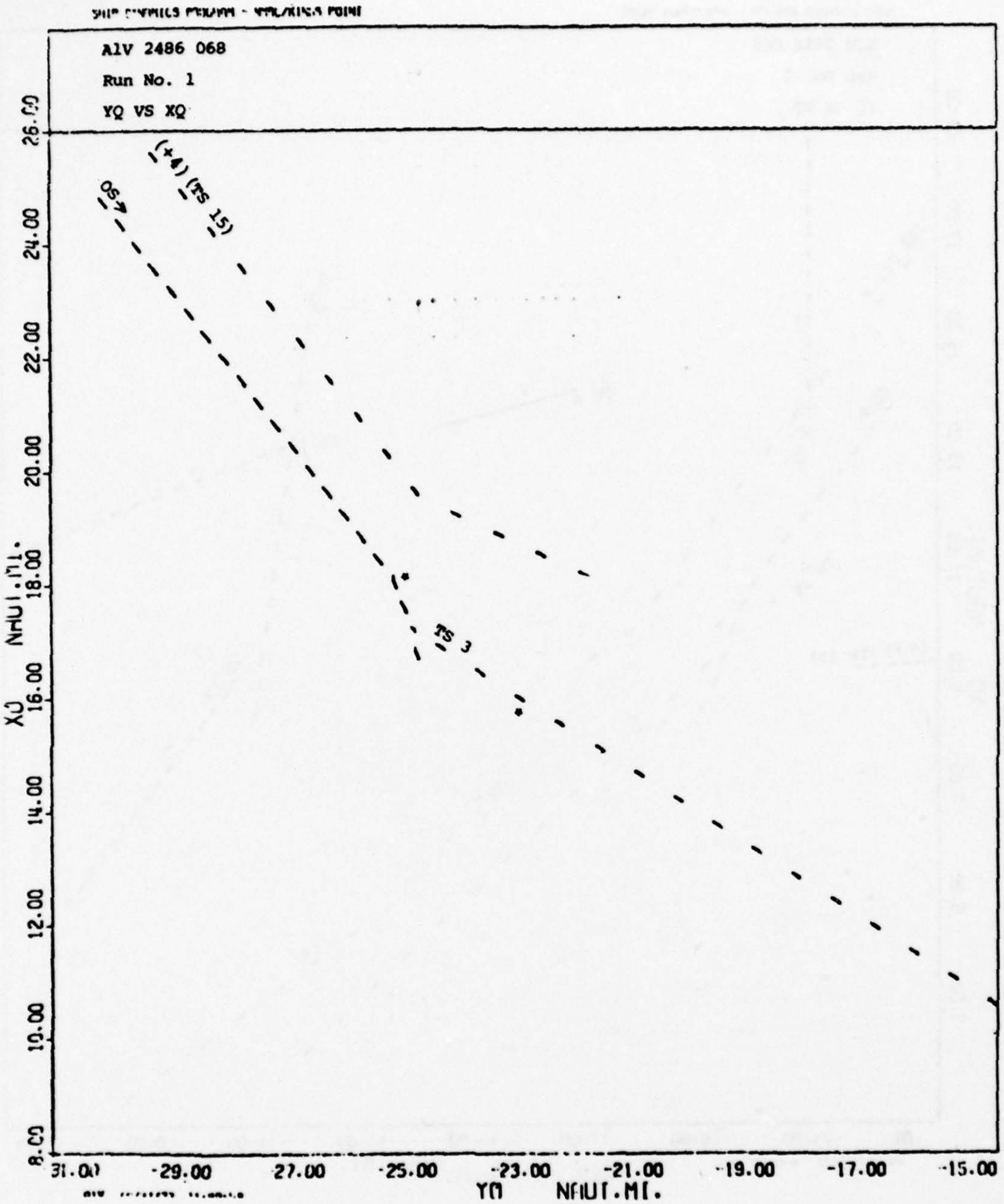
BIV 2484 067
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
-9.00
-7.00
-5.00
-3.00
-1.00
1.00
3.00
5.00
7.00
(TS 15)
TS 16
TS 2
(TS 8)
(TS 9)
(TS 1)
OS
TS 3
(TS 33)


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B2V 2484 067
Run No. 2
YQ VS XQ
(TS 39)
OS
TS 27
XO NAUT.MI.
YO NAUT.MI.
29.00
31.00
33.00
35.00
37.00
39.00
41.00
43.00
45.00
47.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00

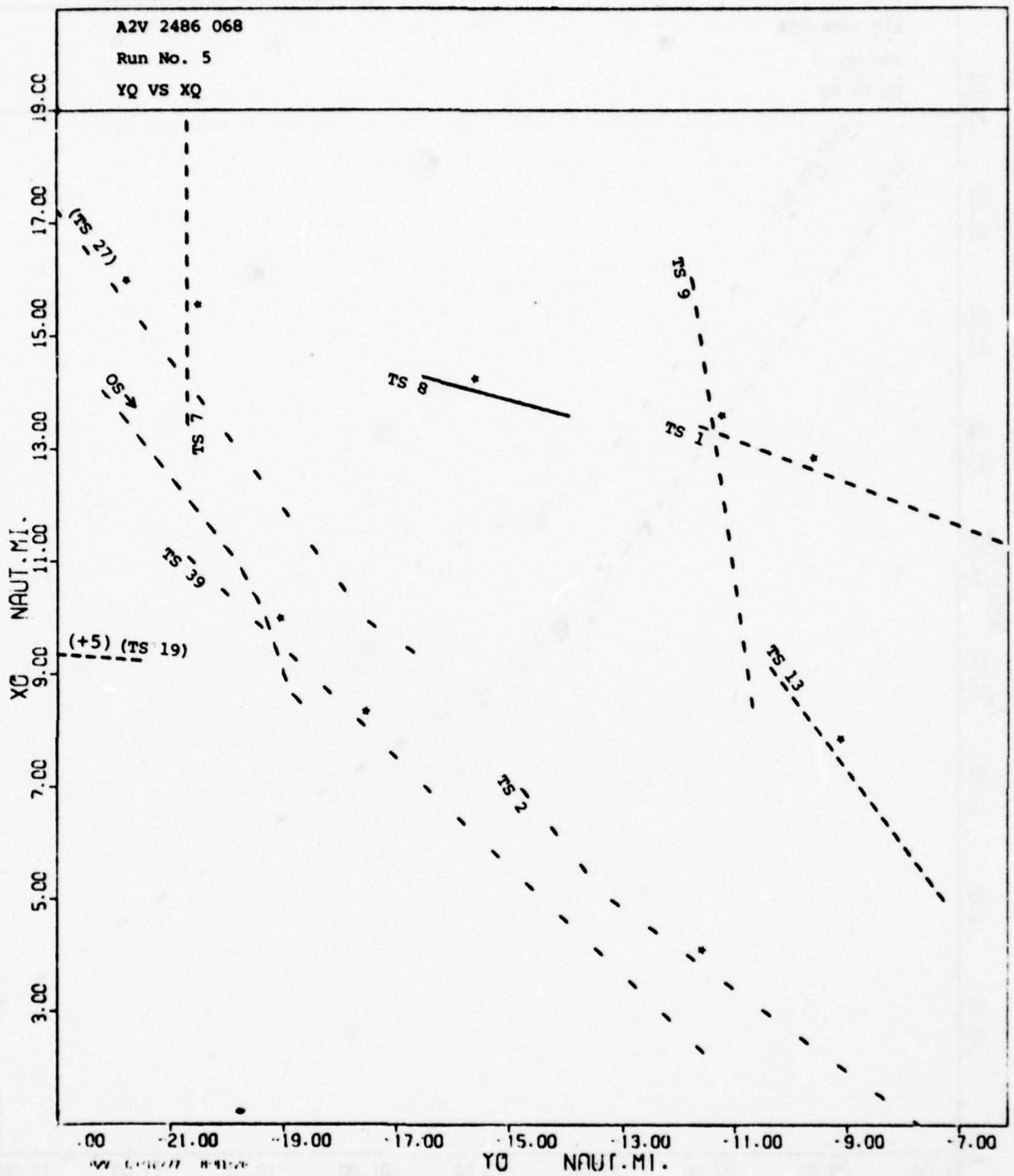


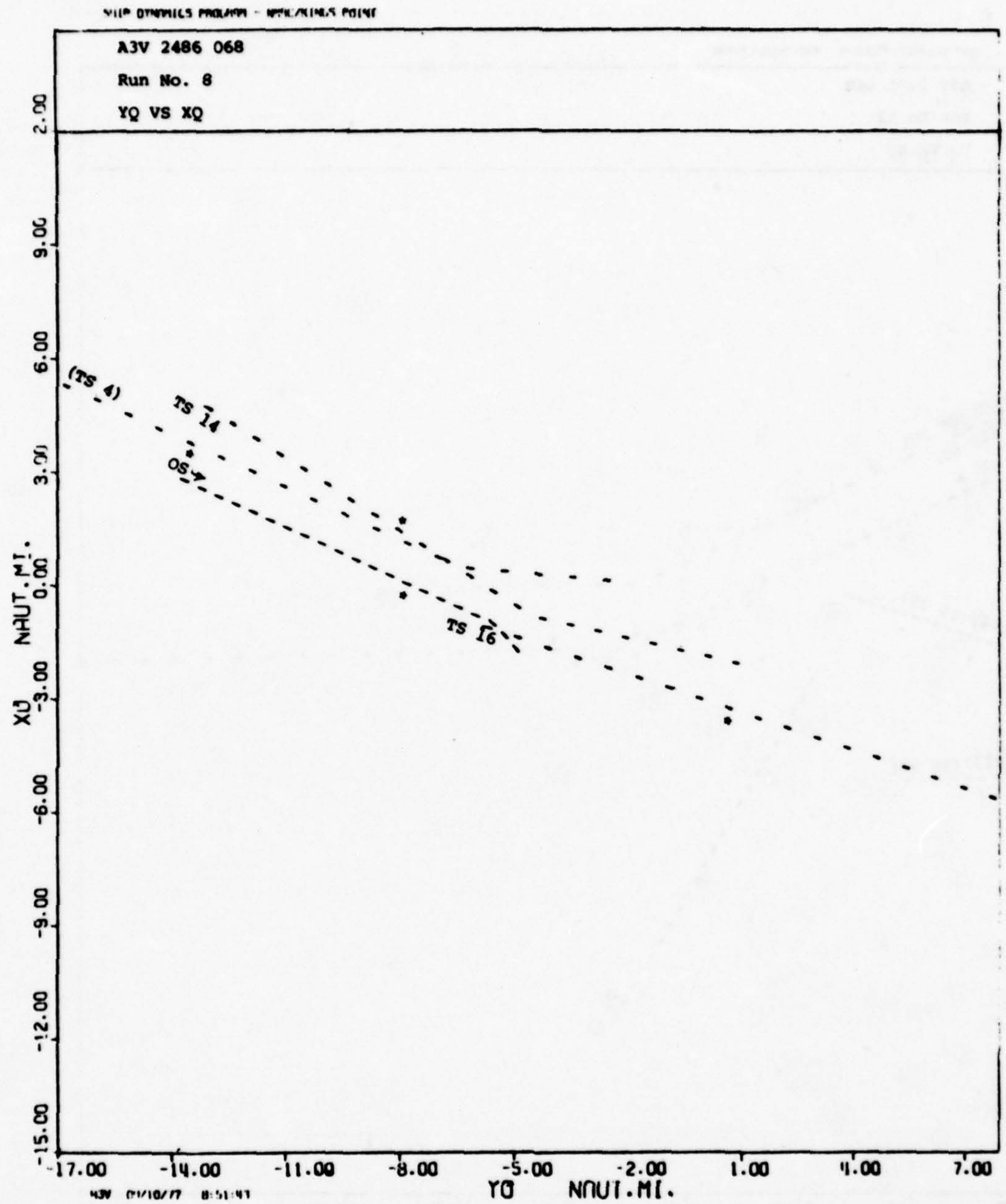
SHIP DYNAMICS PROGRAM - NMRL/KINGS POINT
B3V 2484 067
Run No. 3
YQ VS XQ
XQ NAUT.MI.
62.00
60.00
58.00
56.00
54.00
52.00
50.00
48.00
46.00
44.00
YQ NAUT.MI.
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
(TS 40)
(+2)
TS 26
TS 25
TS 20
TS 5
TS 7
(TS 14)
OS
(TS 31)

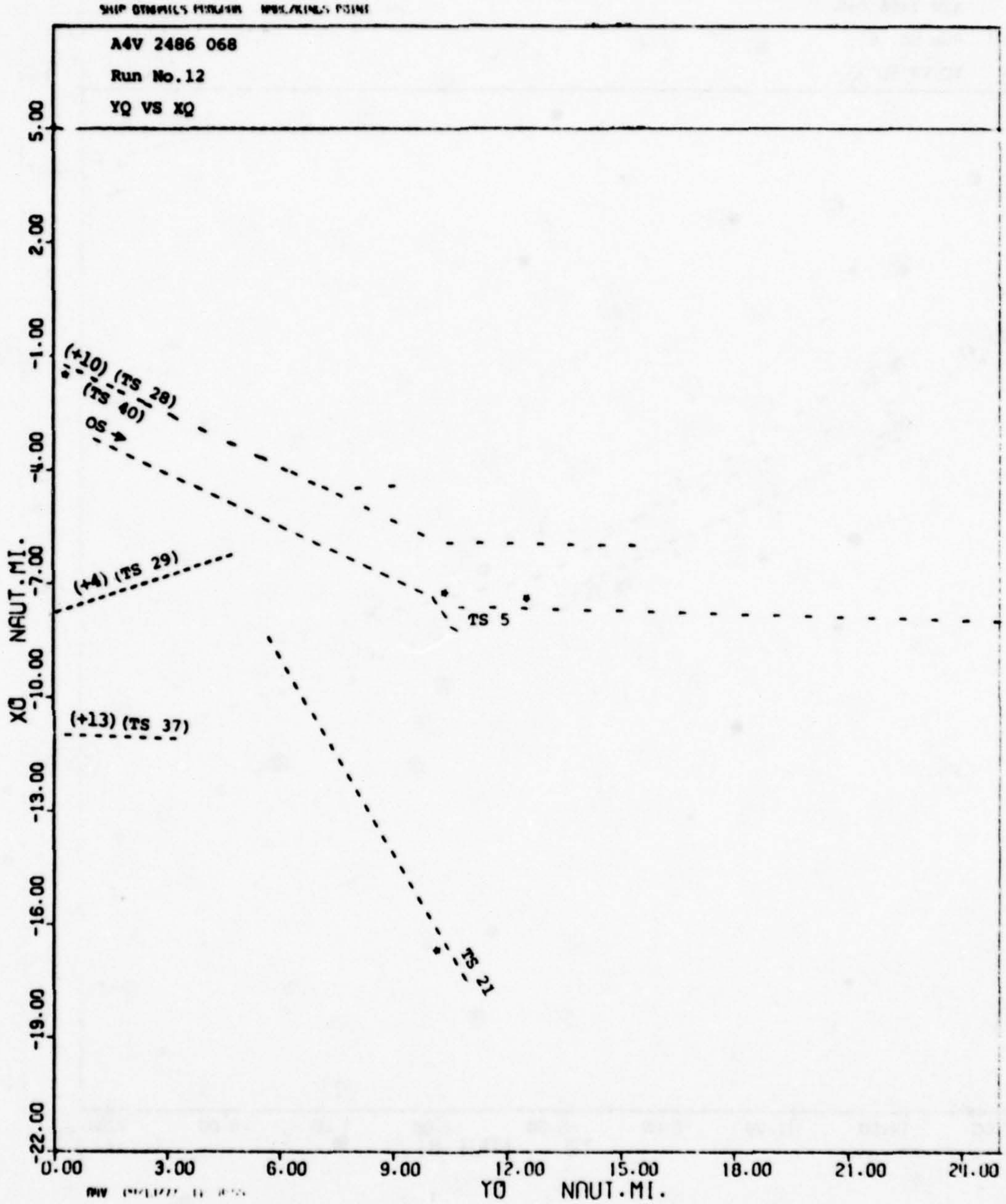

B4V 2484 067
Run No. 5
YQ VS XQ
OS
TS 17
TS 38
TS 6
(+5)
XQ NAUT.MI.
YQ NAUT.MI.
16.50
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
56.00
58.00
60.00
62.00
64.00
66.00
54.00
52.00


AlV 2486 068
Run No. 1
YQ VS XQ
OS 7
(+4) (TS 15)
TS 3
XQ NAUT.MI.
YQ NAUT.MI.
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
-15.00

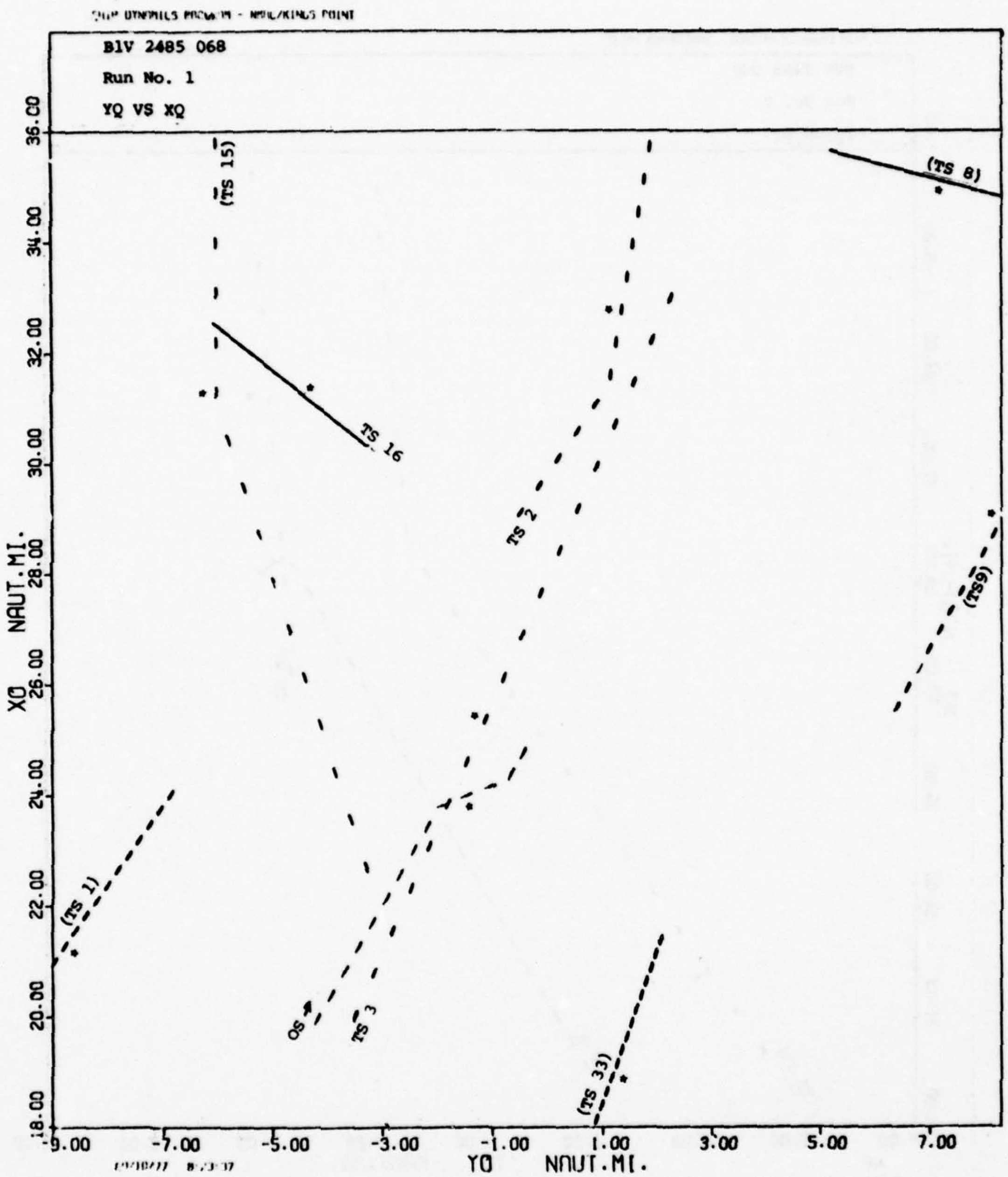
SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT

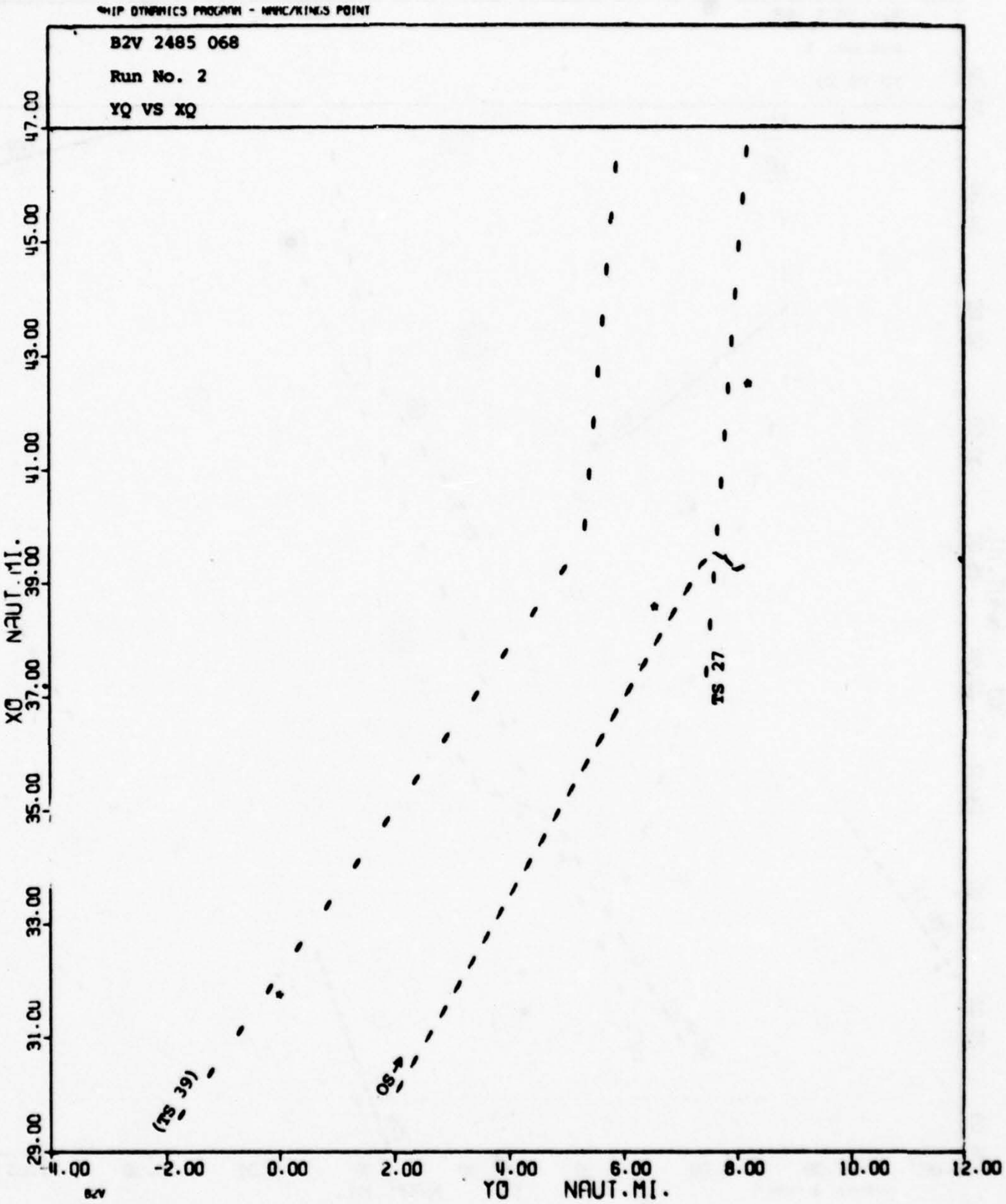


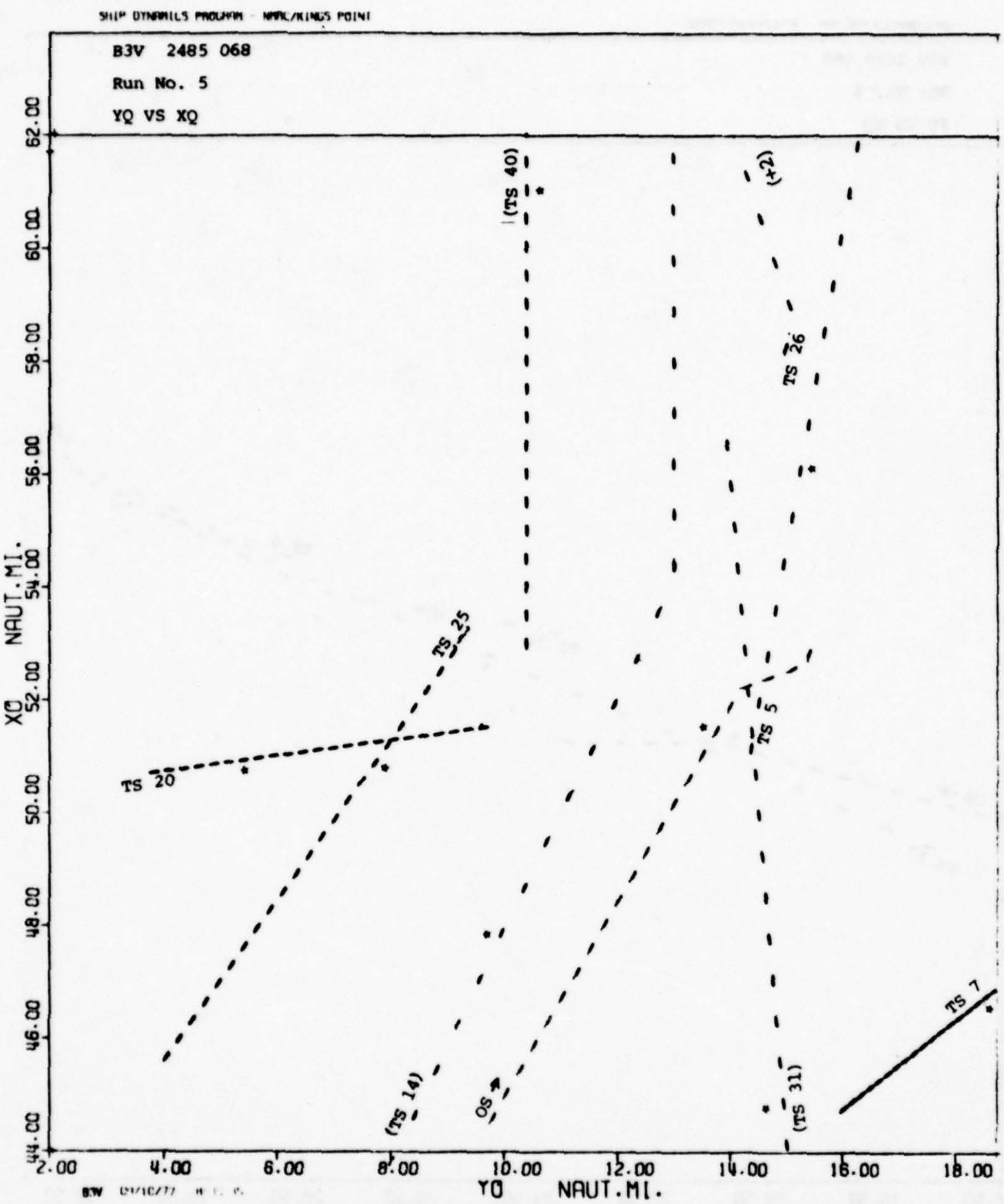

A3V 2486 068
Run No. 8
YQ VS XQ
(TS 4)
TS 14
OS 7
TS 16
XQ NAUT.MI.
YQ NAUT.MI.
2.00
9.00
6.00
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-17.00
-14.00
-11.00
-8.00
-5.00
-2.00
1.00
4.00
7.00

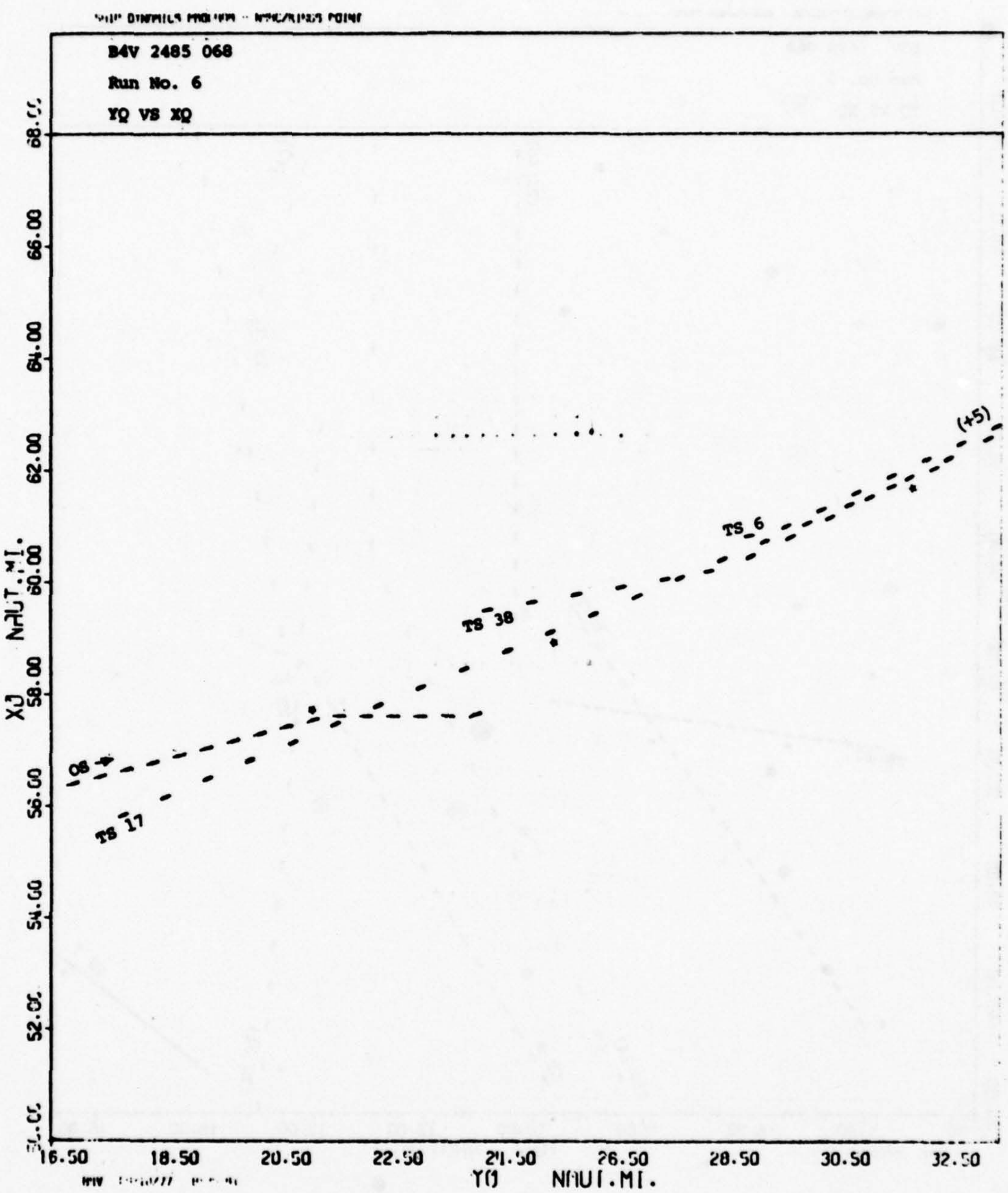


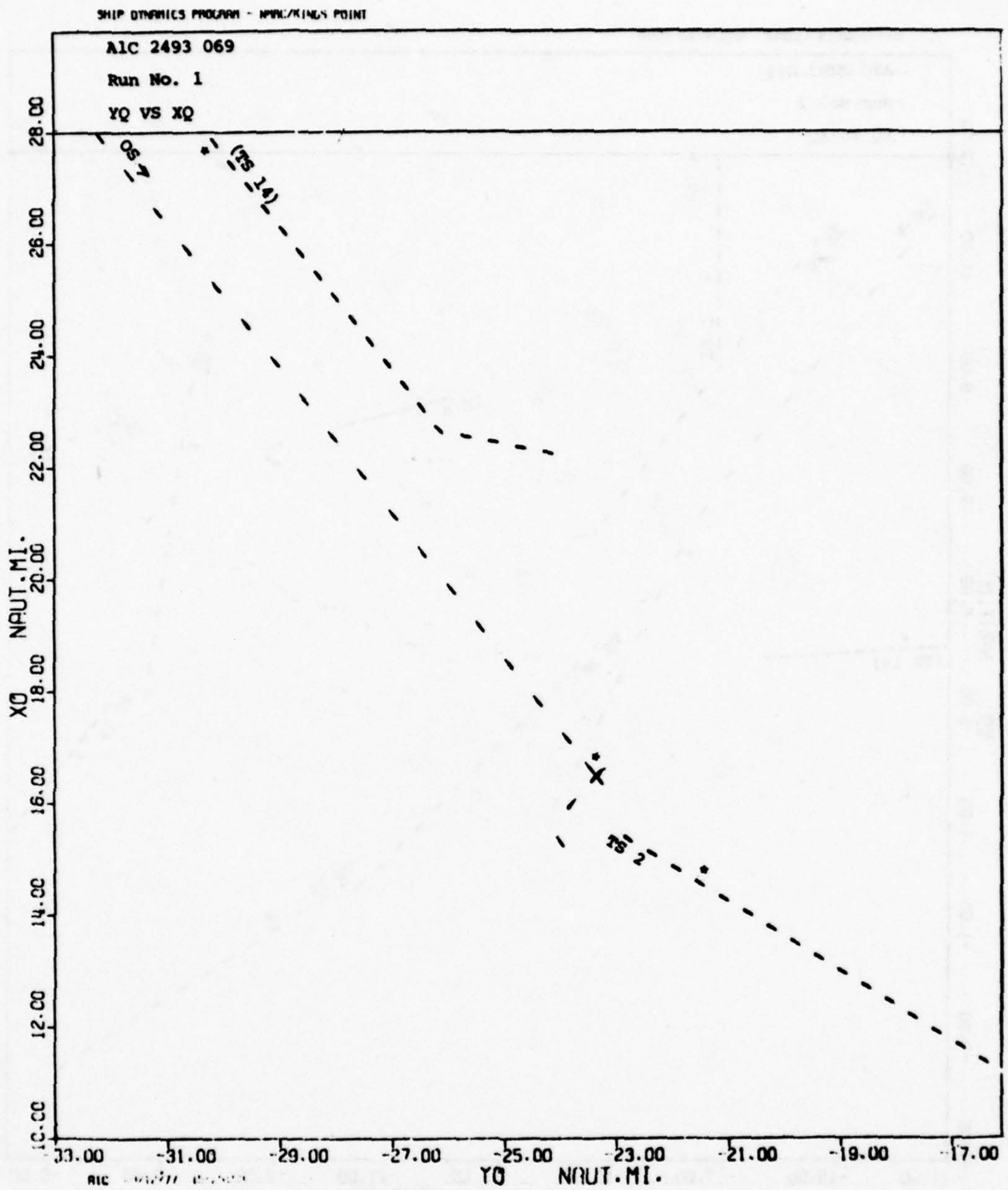
A4V 2486 068
Run No.12
YQ VS XQ
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
XQ NAUT.MI.
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
YQ NAUT.MI.
(+10) (TS 28)
(TS 40)
OS
(+4) (TS 29)
TS 5
(+13) (TS 37)
TS 21


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B1V 2485 068
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
-9.00
-7.00
-5.00
-3.00
-1.00
1.00
3.00
5.00
7.00
(TS 15)
TS 16
TS 2
(TS 8)
(TS9)
(TS 1)
OS
TS 3
(TS 33)

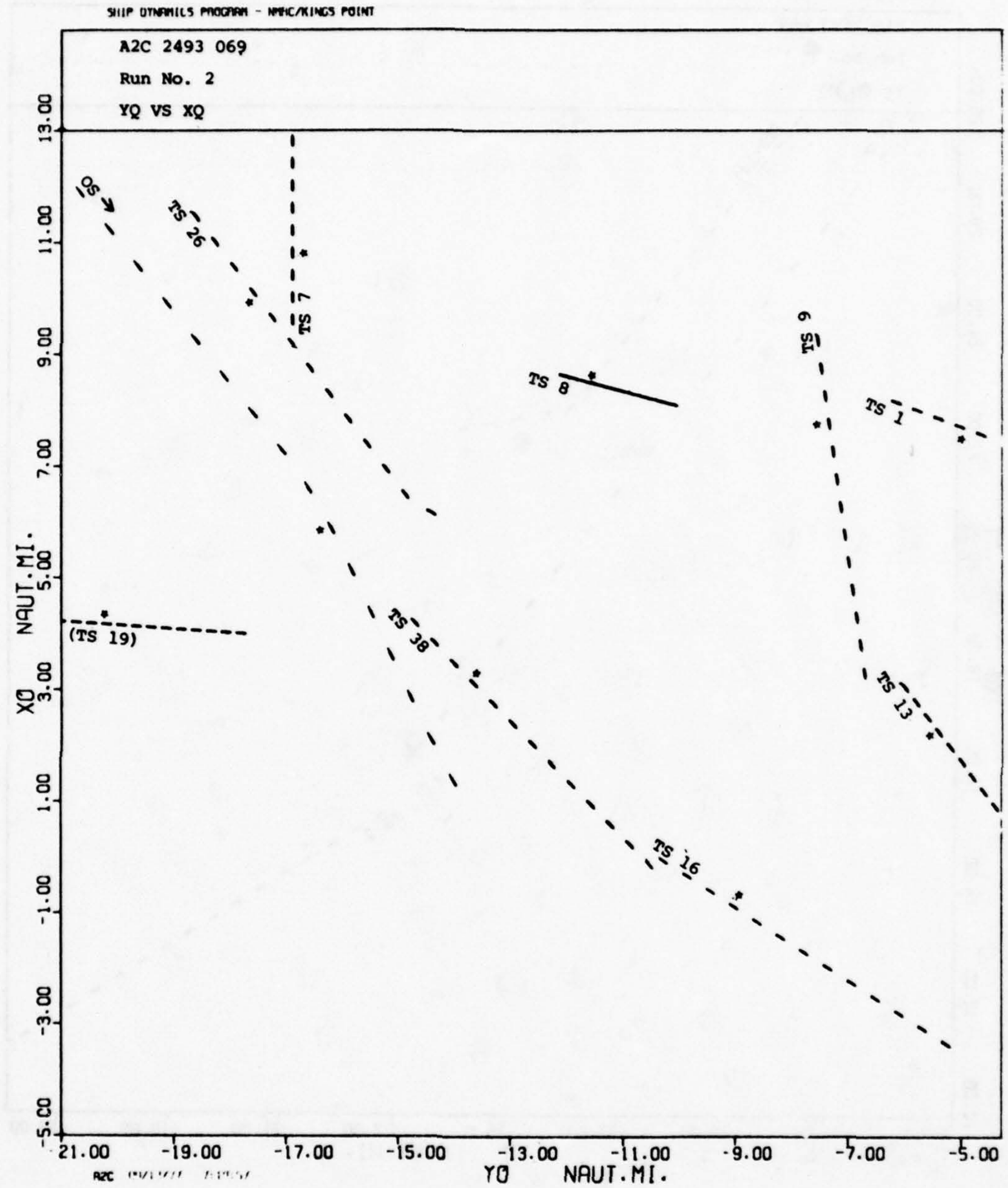

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B2V 2485 068
Run No. 2
YQ VS XQ
XQ NAUT.MI.
29.00
31.00
33.00
35.00
37.00
39.00
41.00
43.00
45.00
47.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
YQ NAUT.MI.
TS 39
OS
TS 27


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B3V 2485 068
Run No. 5
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
44.00
46.00
48.00
50.00
52.00
54.00
56.00
58.00
60.00
62.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
TS 20
TS 25
(TS 40)
(+2)
TS 26
TS 5
(TS 14)
OS
(TS 31)
TS 7

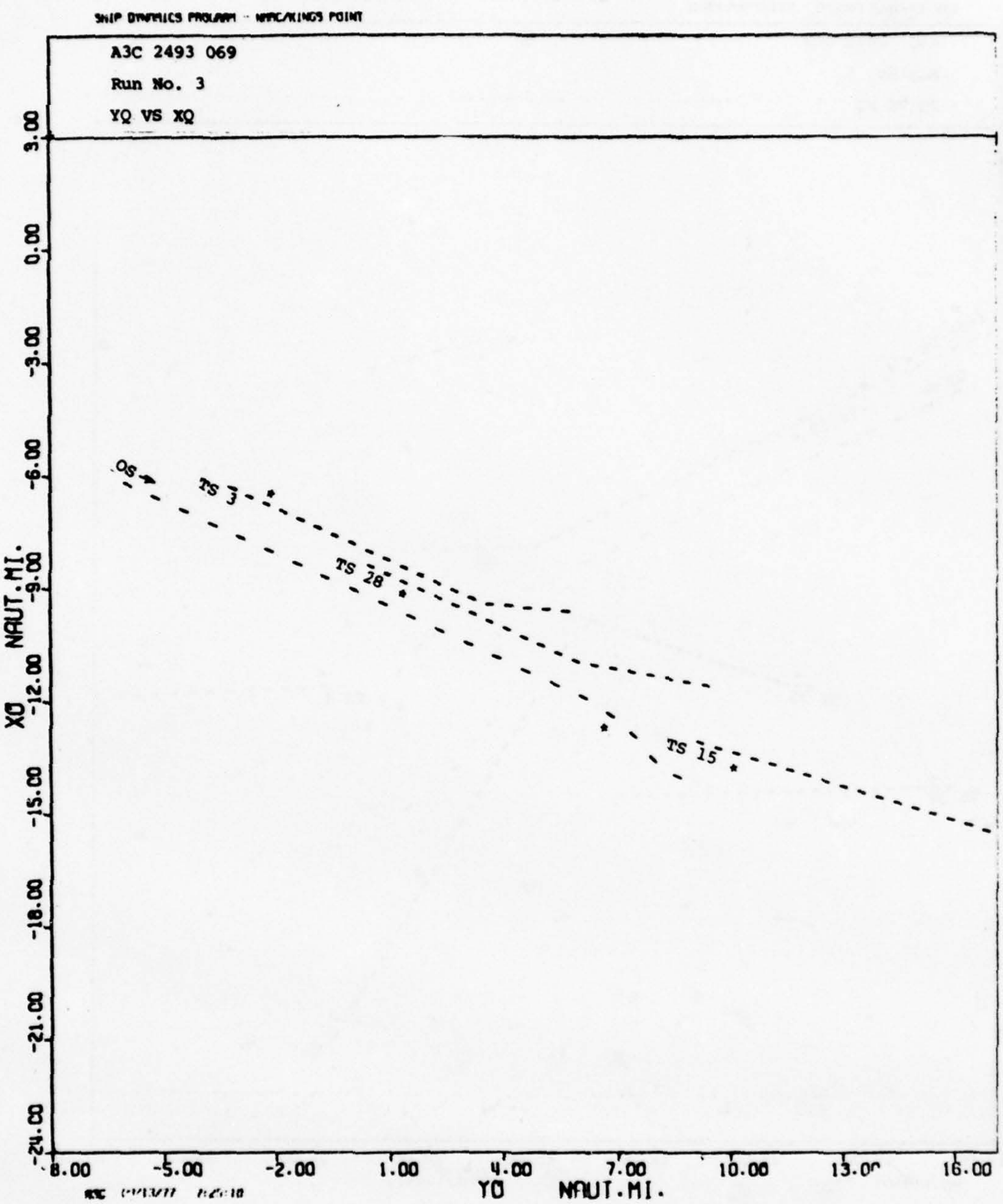

B4V 2485 068
Run No. 6
YQ VS XQ
XJ NAUT.MI.
YQ NAUT.MI.
68.00
66.00
64.00
62.00
60.00
58.00
56.00
54.00
52.00
16.50
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
TS 38
TS 6
TS 17
08
(+5)

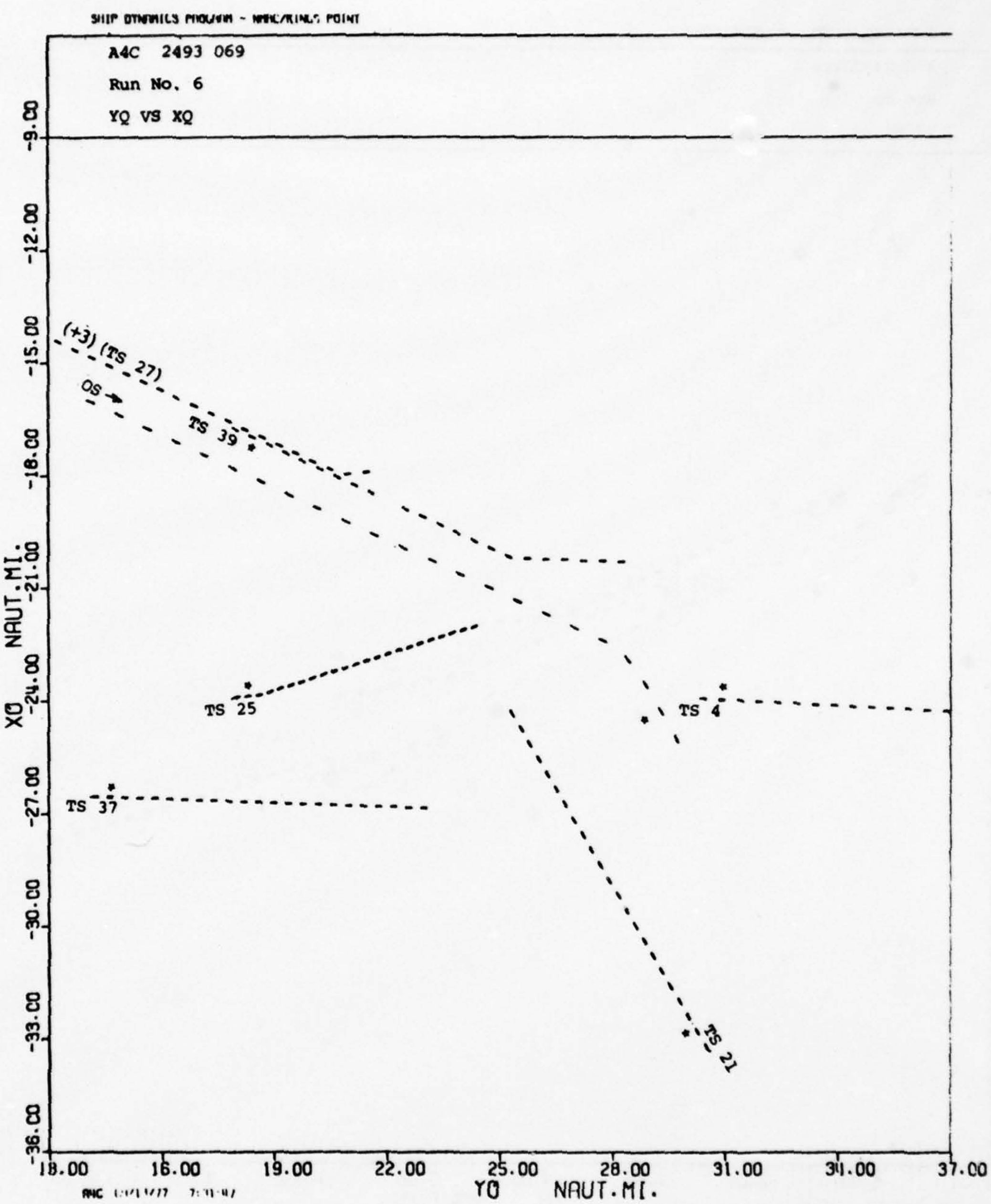


SHIP DYNAMICS PROGRAM - MARAD/KINGS POINT
A1C 2493 069
Run No. 1
YQ VS XQ
XQ NAUT.MI.
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
-33.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
YQ NAUT.MI.
OS 7
TS 14
TS 2

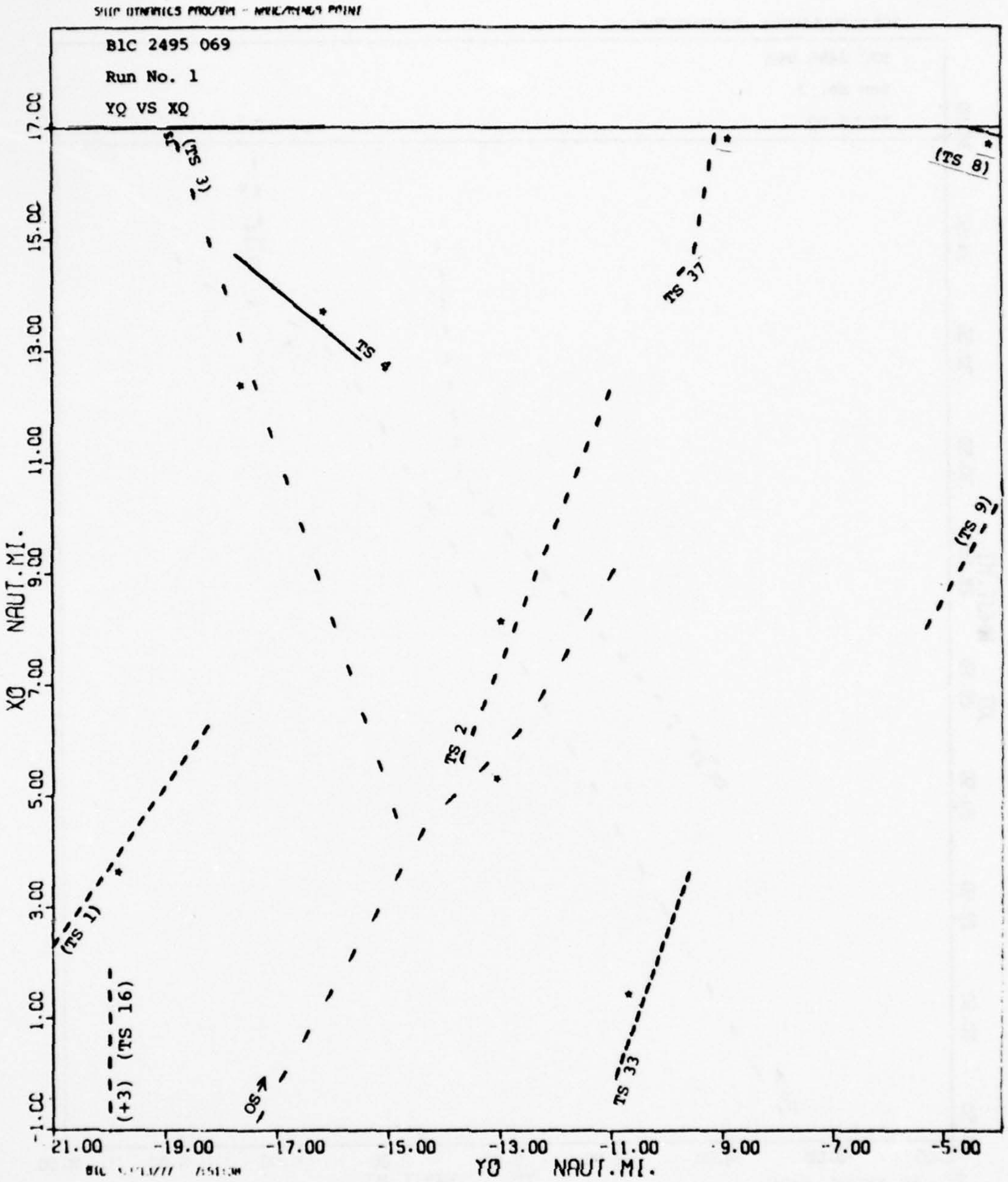


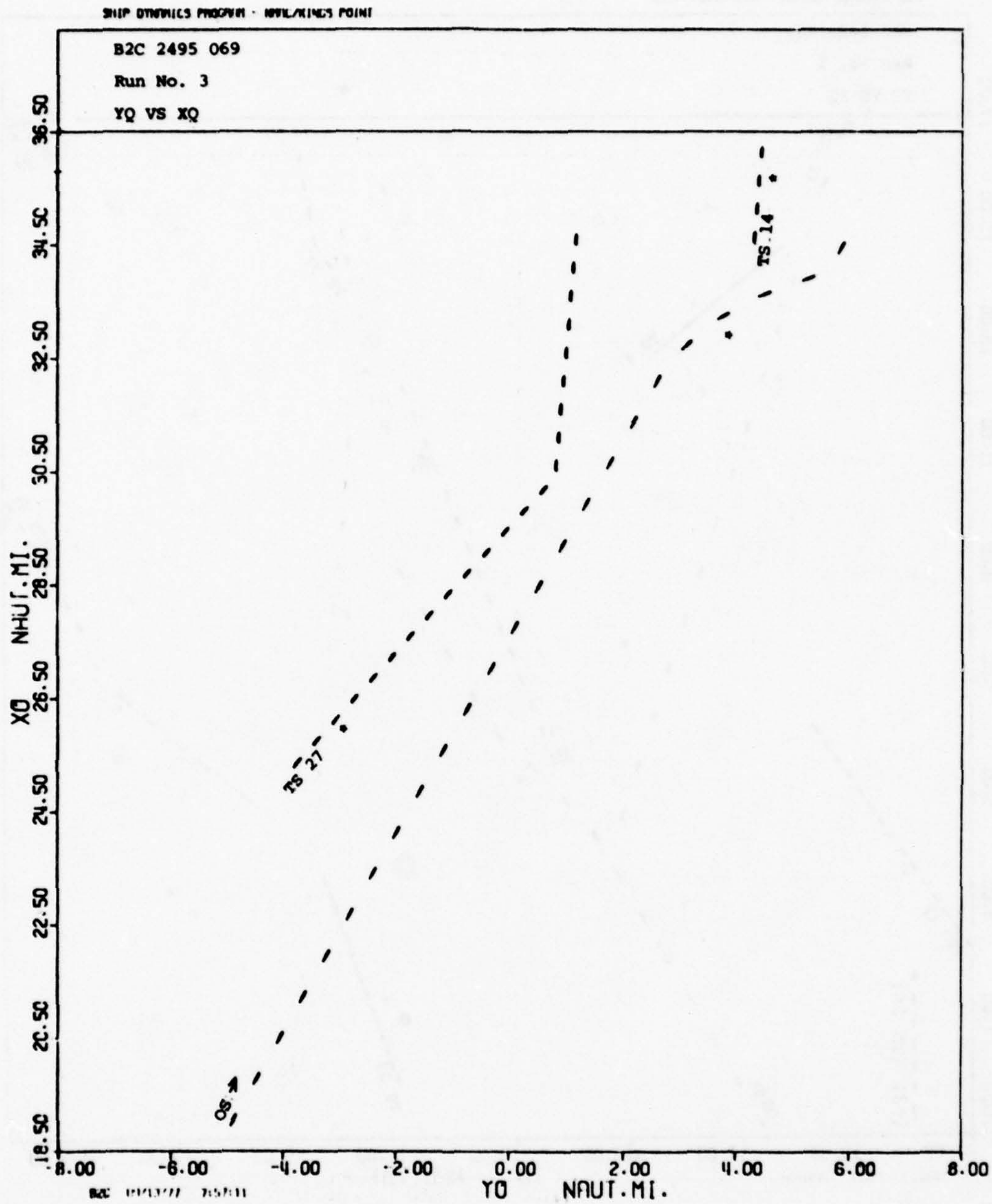
SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A2C 2493 069
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-3.00
-5.00
21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5.00
OS
TS 26
TS 7
TS 8
TS 9
TS 1
(TS 19)
TS 38
TS 13
TS 16

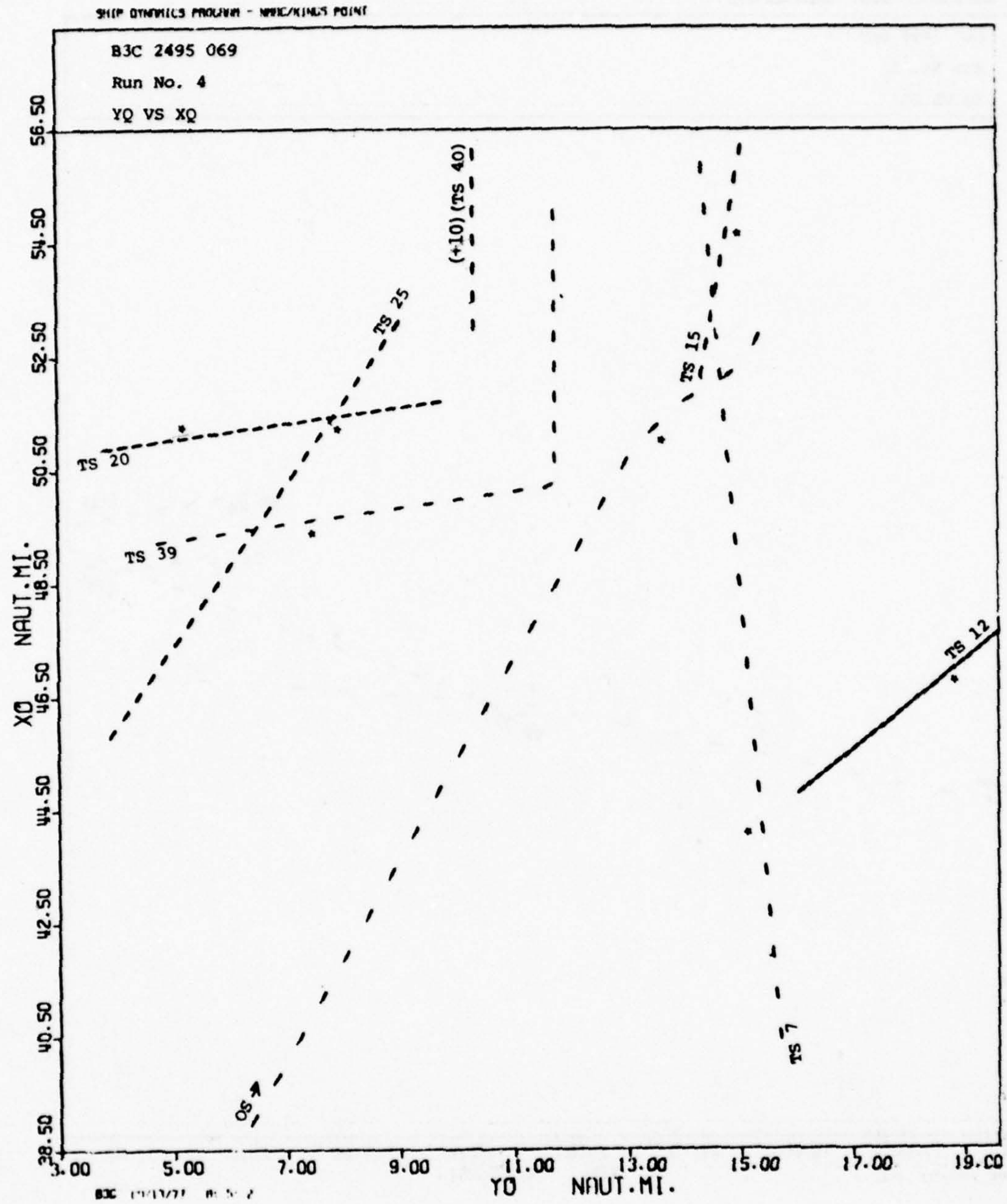

SHIP DYNAMICS PROGRAM - MARAD/KINGS POINT
A3C 2493 069
Run No. 3
YQ VS XQ
OS
TS 3
TS 28
TS 15
XQ NAUT.MI.
YQ NAUT.MI.
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-8.00
-5.00
-2.00
1.00
4.00
7.00
10.00
16.00

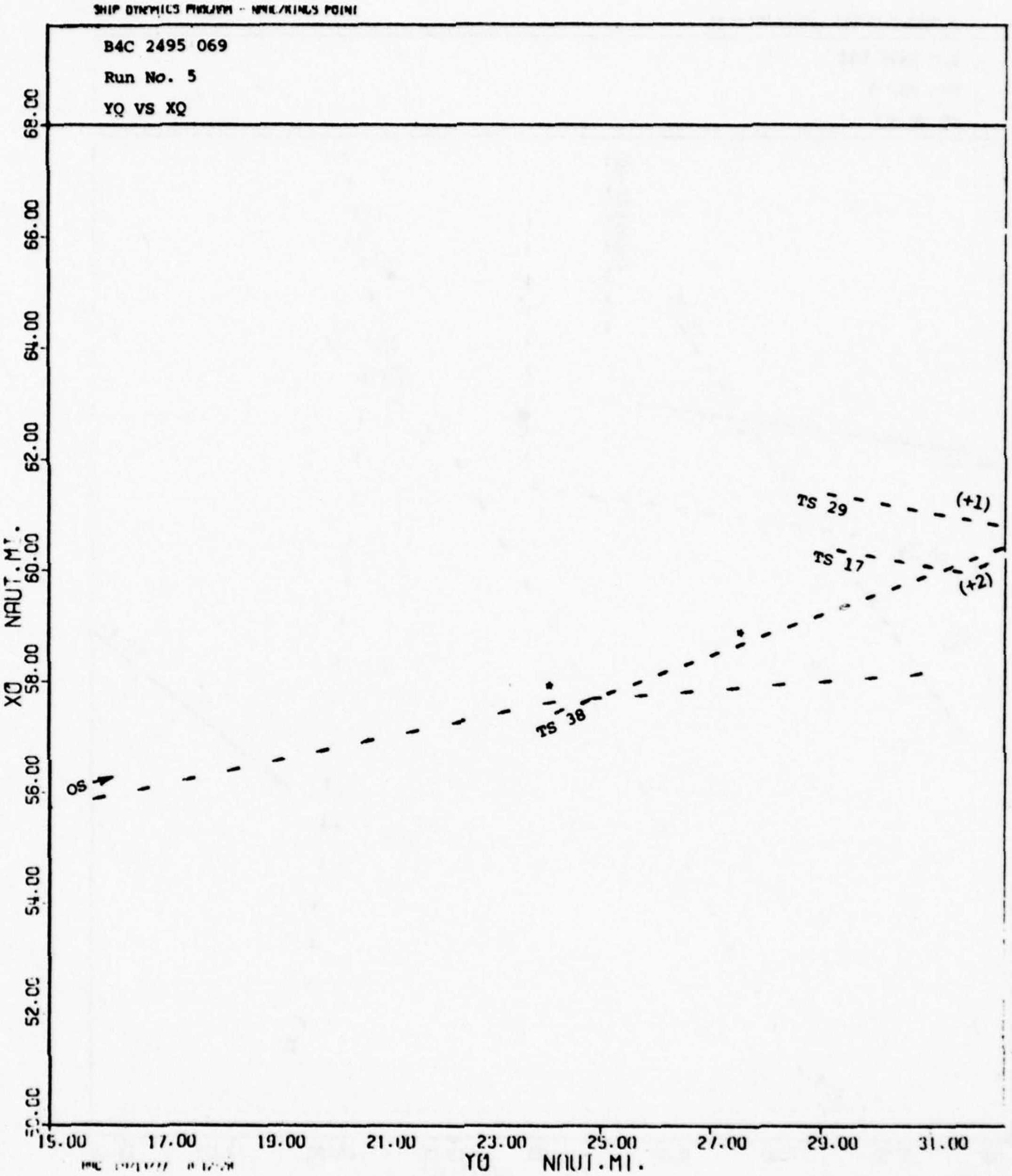


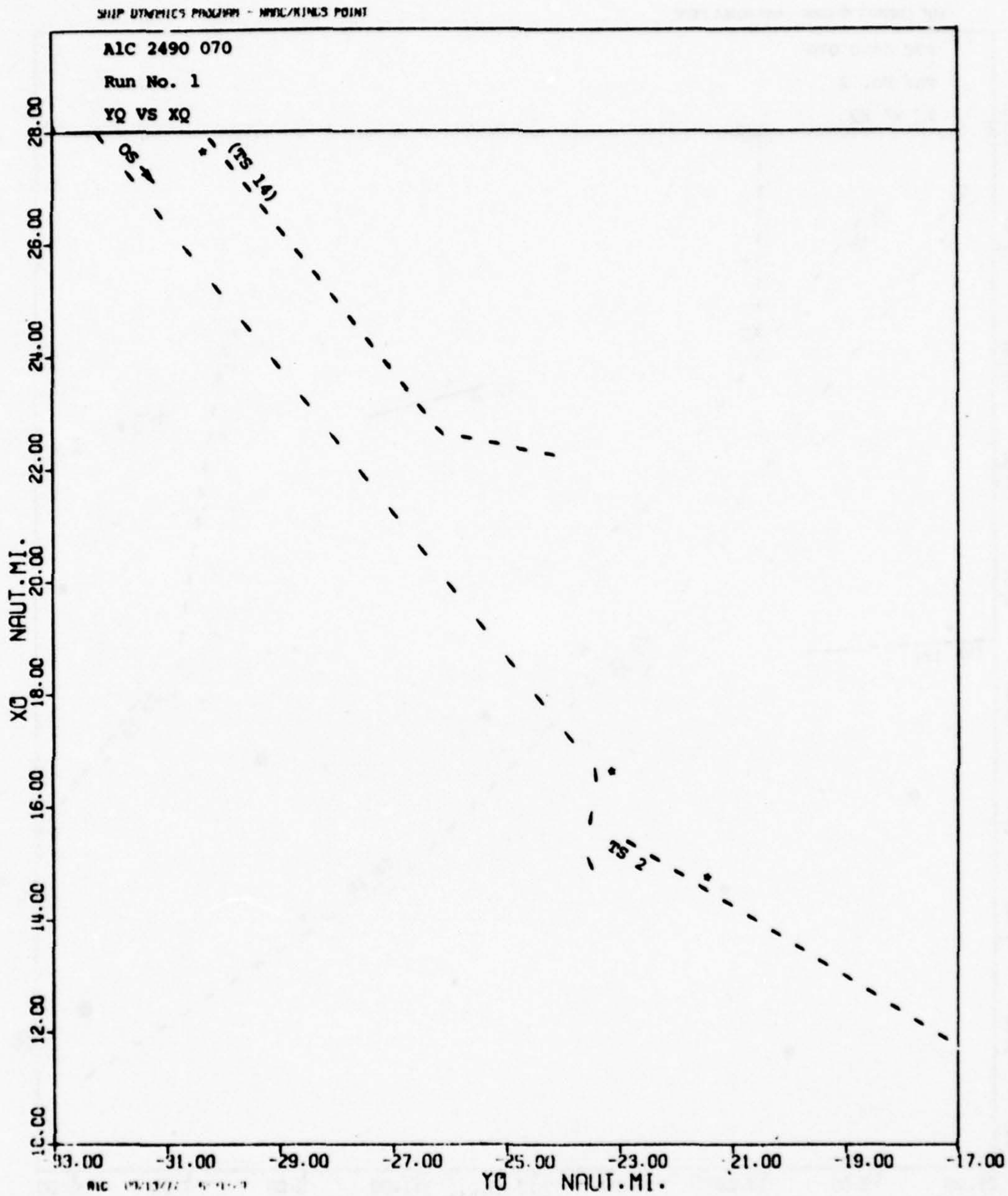
A4C 2493 069
Run No. 6
YQ VS XQ
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-27.00
-30.00
-33.00
-36.00
XQ NAUT.MI.
(+3) (TS 27)
OS
TS 39
TS 25
TS 4
TS 37
TS 21
13.00
16.00
19.00
22.00
25.00
28.00
31.00
34.00
37.00
YQ NAUT.MI.

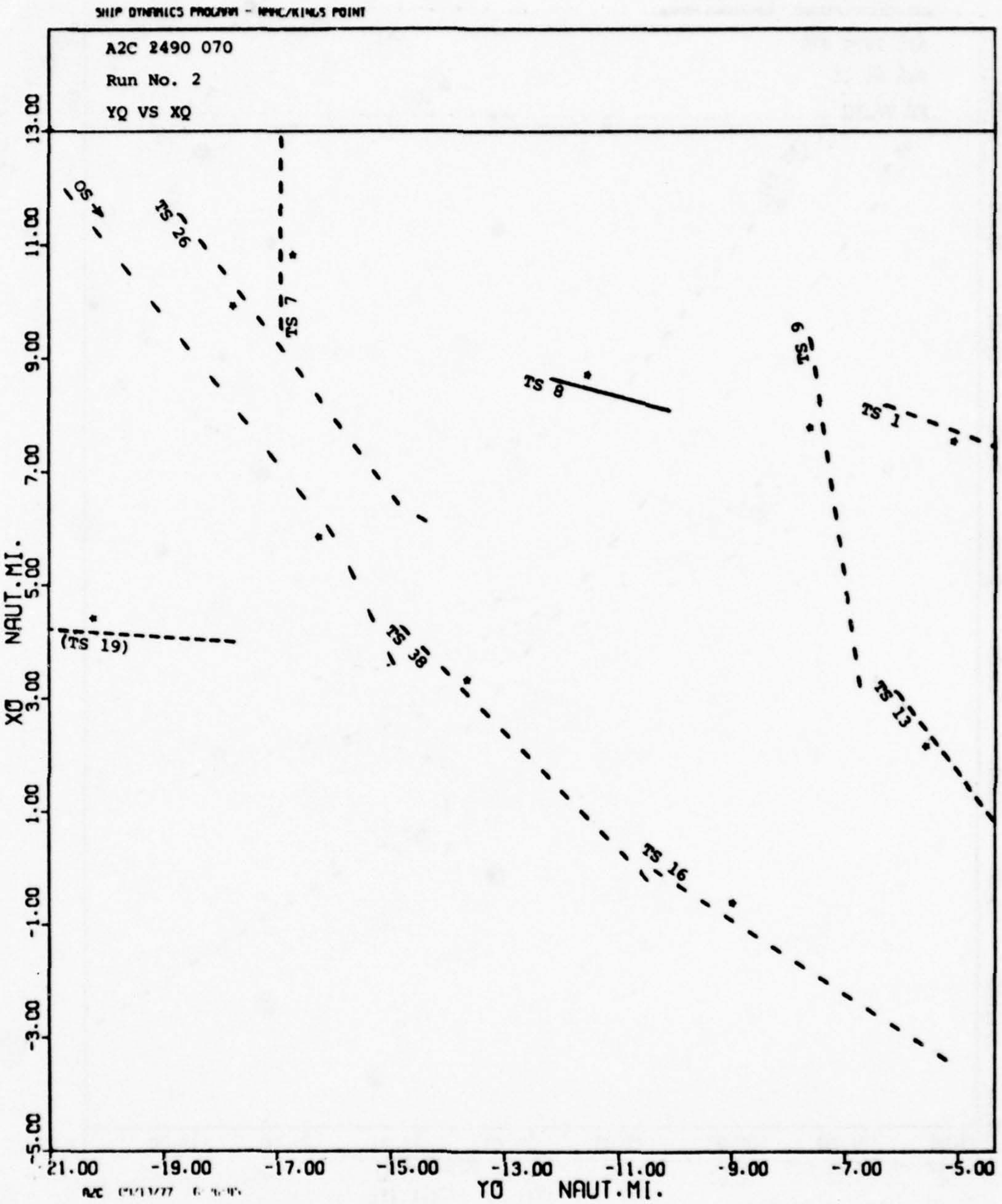

B1C 2495 069
Run No. 1
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5.00
TS 4
TS 37
(TS 8)
(TS 9)
TS 2
(TS 1)
(TS 16)
(+3)
OS
TS 33


B2C 2495 069
Run No. 3
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
TS 27
TS 14
OS
36.50
34.50
32.50
30.50
28.50
26.50
24.50
22.50
20.50
18.50
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00

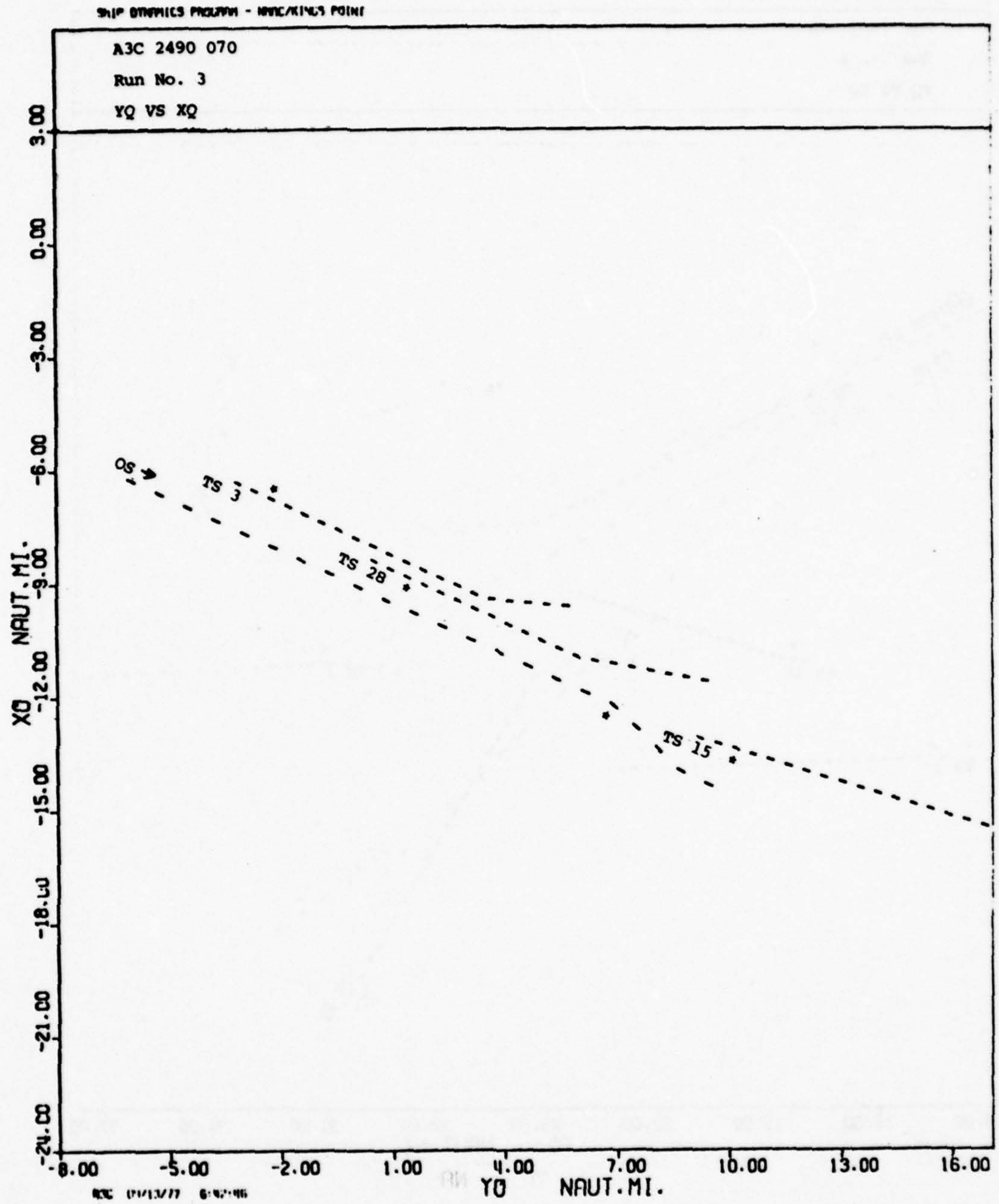

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B3C 2495 069
Run No. 4
YO VS XO
XO NAUT.MI.
YO NAUT.MI.
56.50
54.50
52.50
50.50
48.50
46.50
44.50
42.50
40.50
38.50
3.00
5.00
7.00
9.00
11.00
13.00
15.00
17.00
19.00
TS 25
TS 20
TS 39
(+10)(TS 40)
TS 15
TS 12
TS 7
OS


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B4C 2495 069
Run No. 5
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
TS 38
TS 29
TS 17
(+1)
(+2)
68.00
66.00
64.00
62.00
60.00
58.00
56.00
54.00
52.00
15.00
17.00
19.00
21.00
23.00
25.00
27.00
29.00
31.00

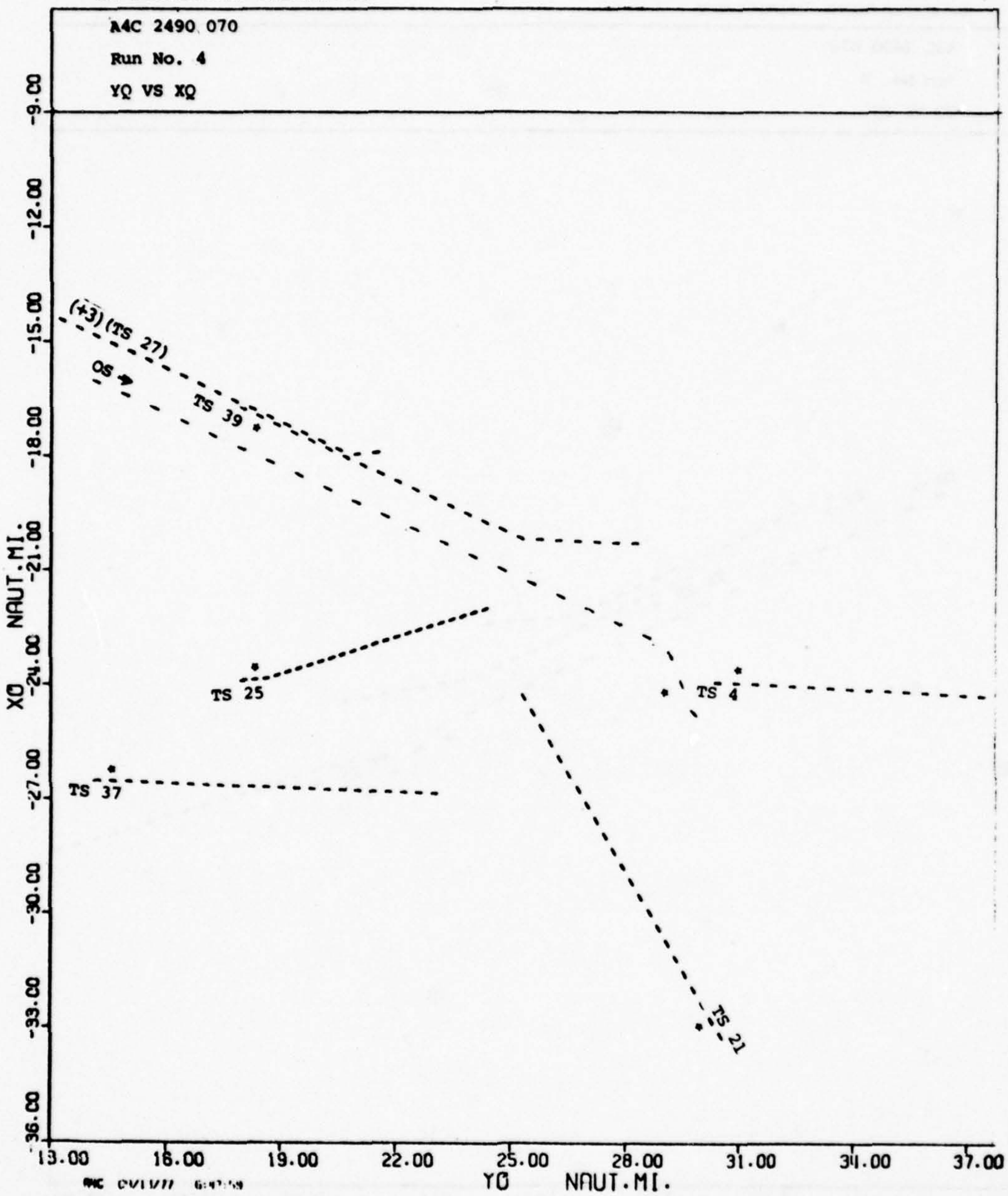

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A1C 2490 070
Run No. 1
YQ VS XQ
OS
(TS 14)
TS 2
XO NAUT.MI.
YO NAUT.MI.
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
-33.00
-31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00

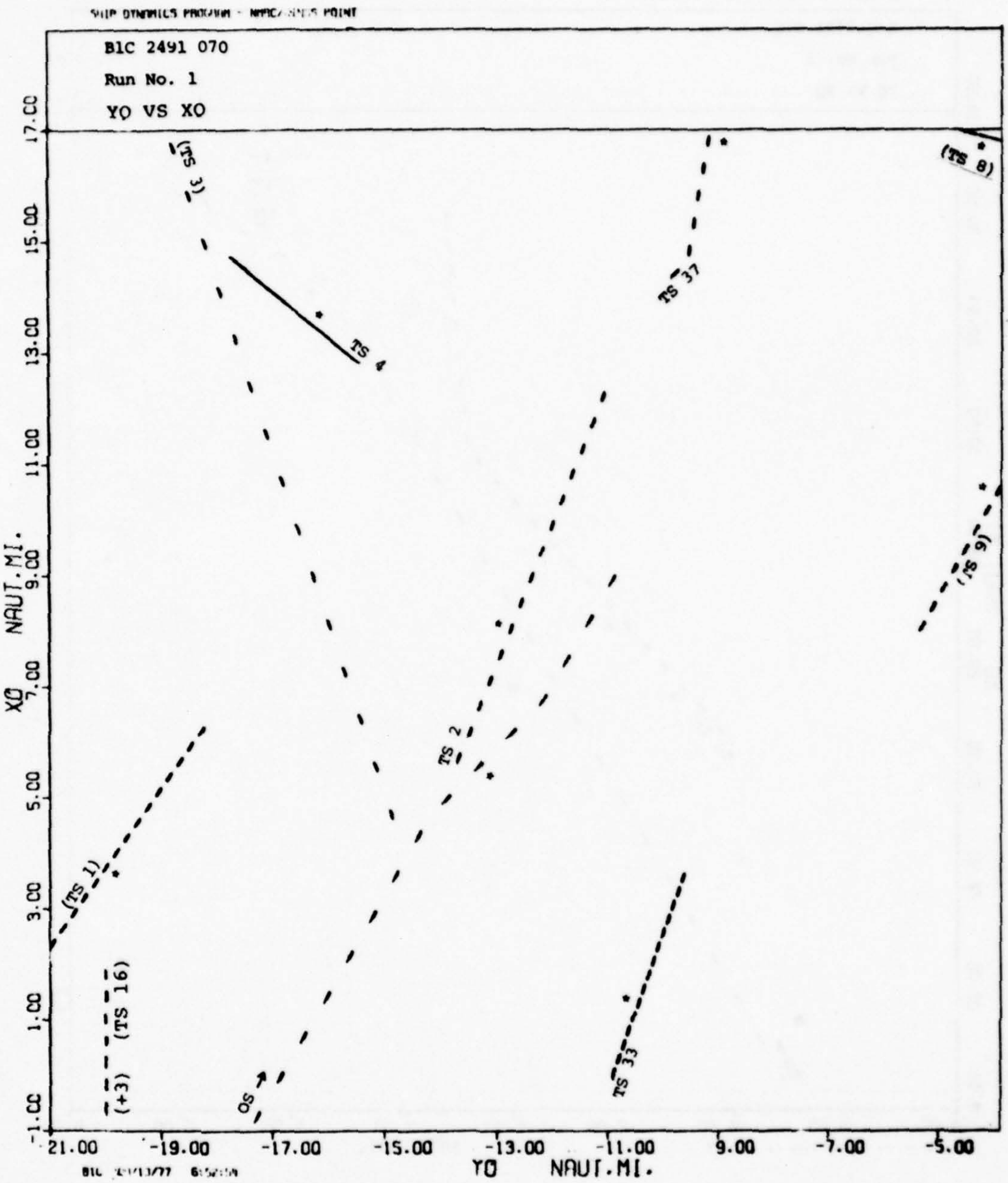


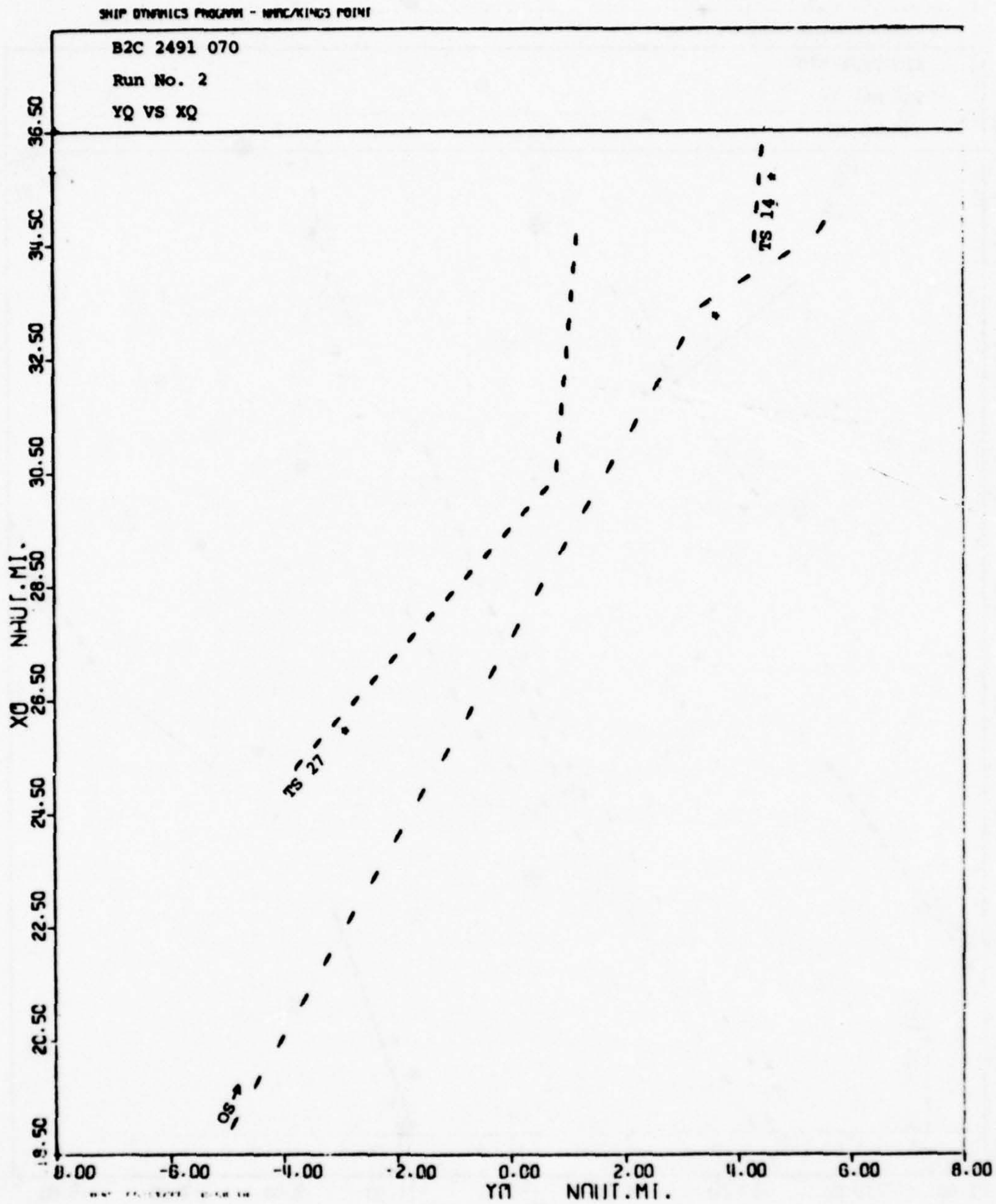
SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A2C 2490 070
Run No. 2
YO VS XO
OS
TS 26
TS 7
TS 8
TS 9
TS 1
TS 19
TS 38
TS 13
TS 16
XO NAUT.MI.
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-3.00
-5.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
-5.00
YO NAUT.MI.

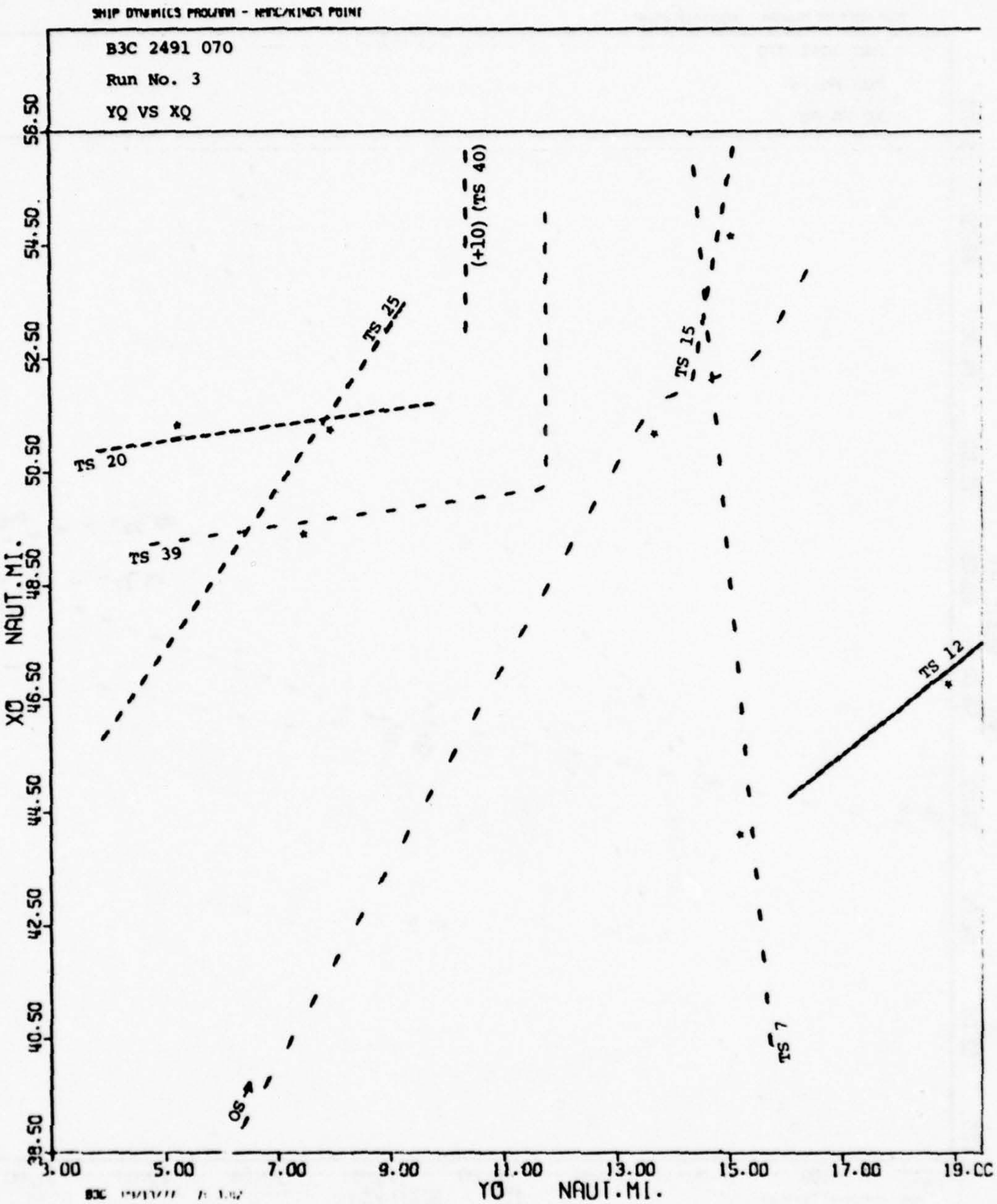

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A3C 2490 070
Run No. 3
YQ VS XQ
XO NAUT.MI.
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-18.00
-21.00
-24.00
-8.00
-5.00
-2.00
1.00
4.00
7.00
10.00
13.00
16.00
YO NAUT.MI.
OS
TS 3
TS 28
TS 15

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT

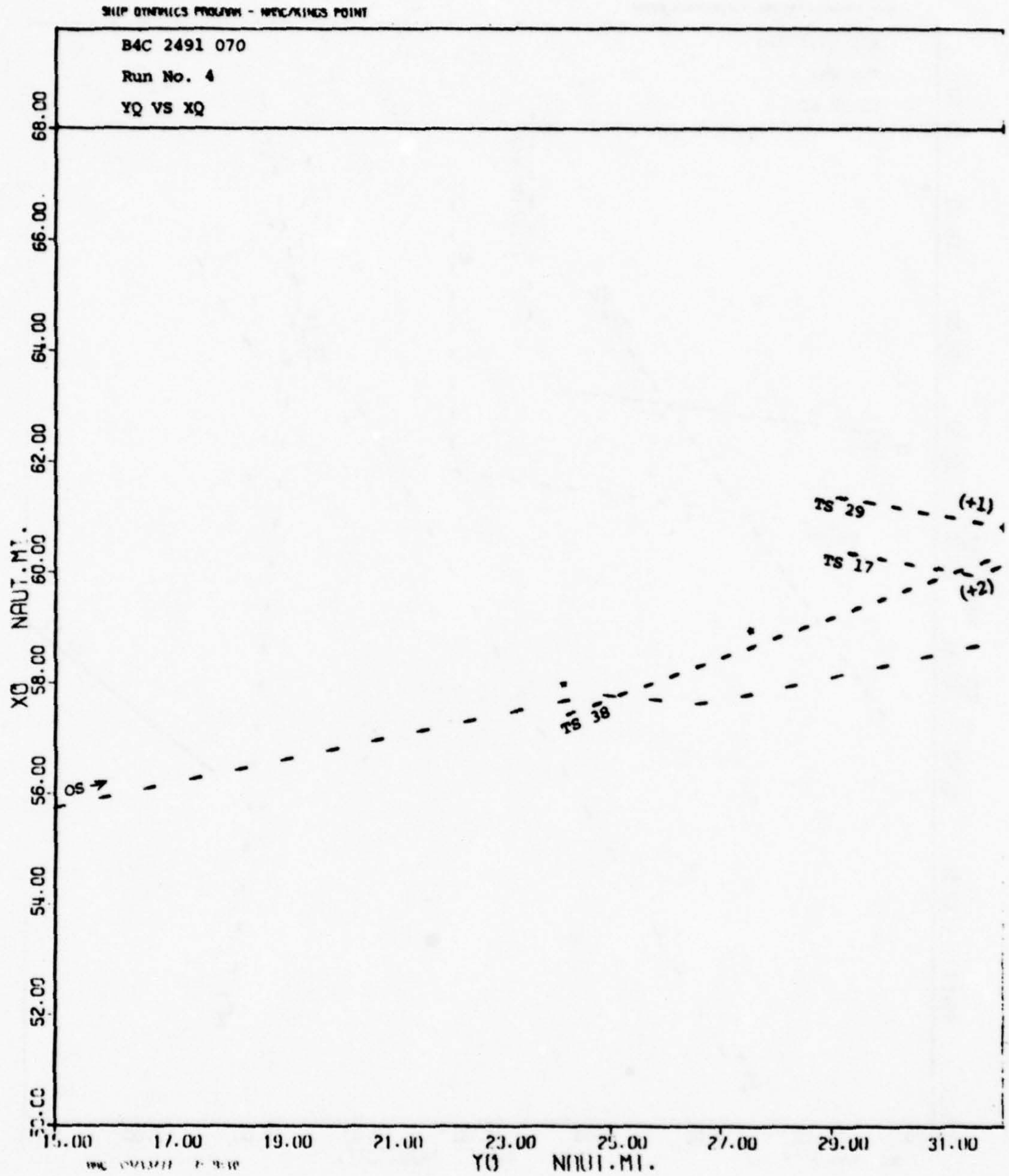


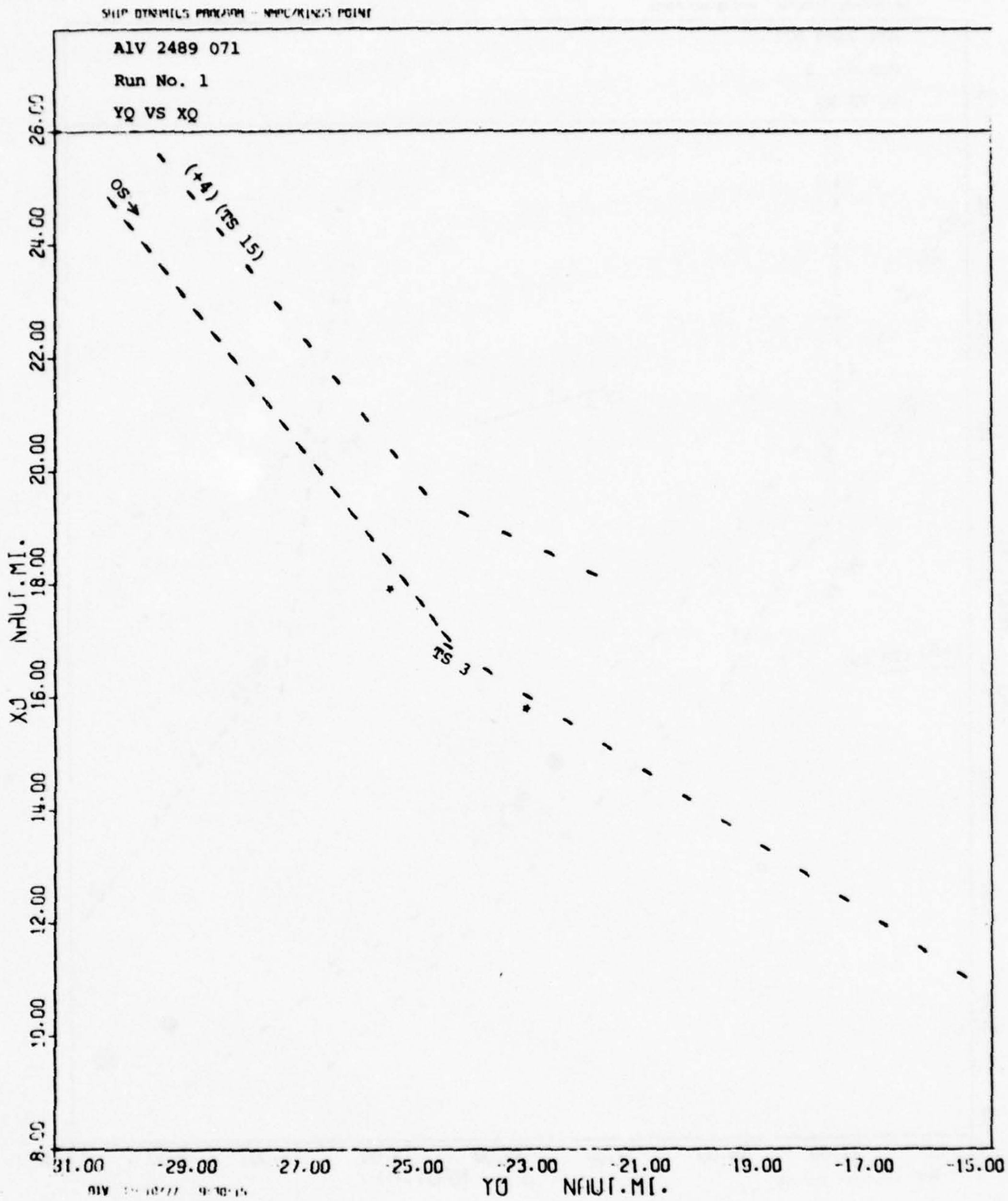

B1C 2491 070
Run No. 1
YO VS XO
XO NAUT.MI.
YO NAUT.MI.
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
9.00
-7.00
-5.00
(TS 3)
TS 4
TS 37
(TS 8)
(TS 9)
TS 2
(TS 1)
(TS 16)
(+3)
OS
TS 33

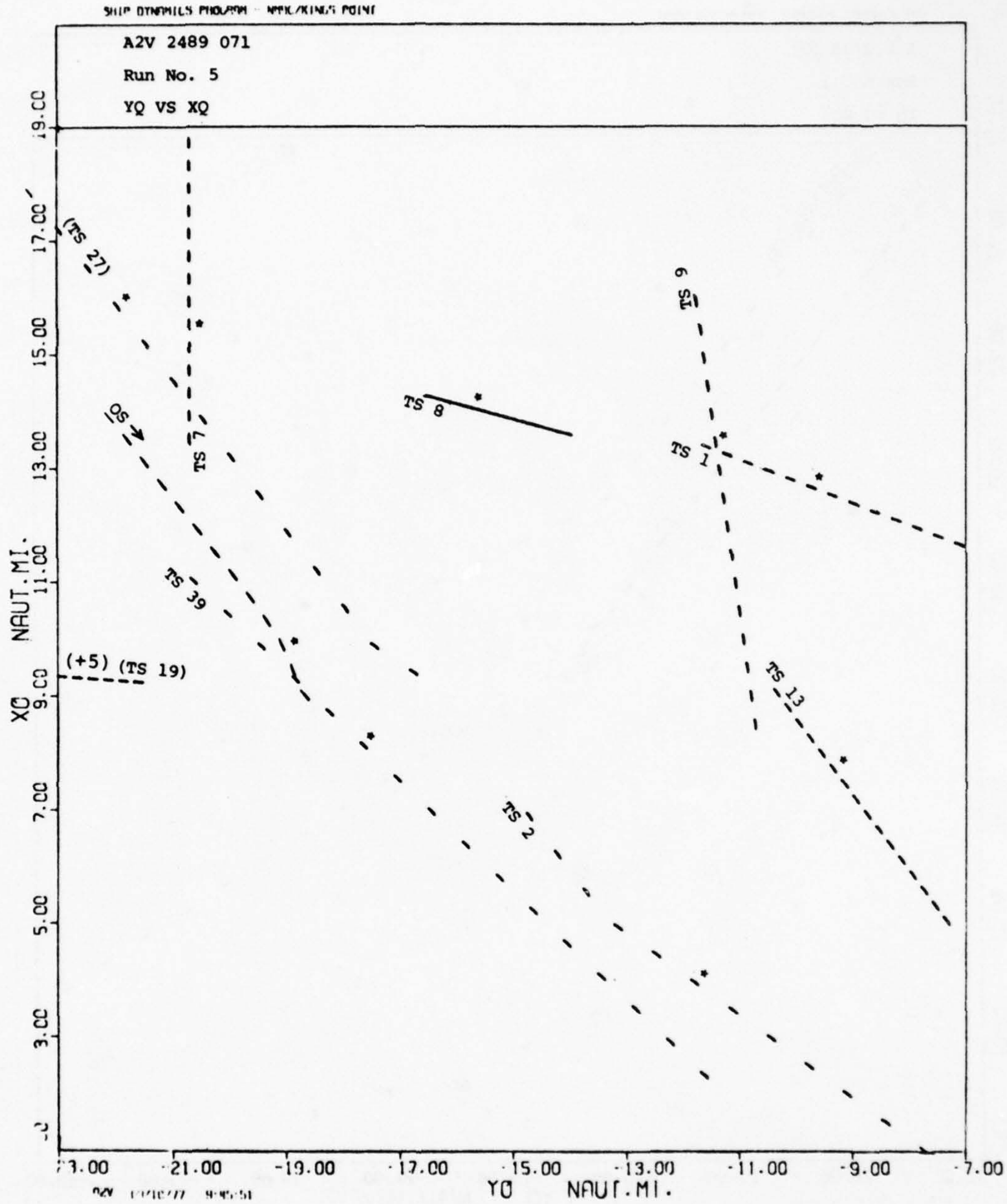

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B2C 2491 070
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
TS 14
TS 27
OS
36.50
34.50
32.50
30.50
28.50
26.50
24.50
22.50
20.50
19.50
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00



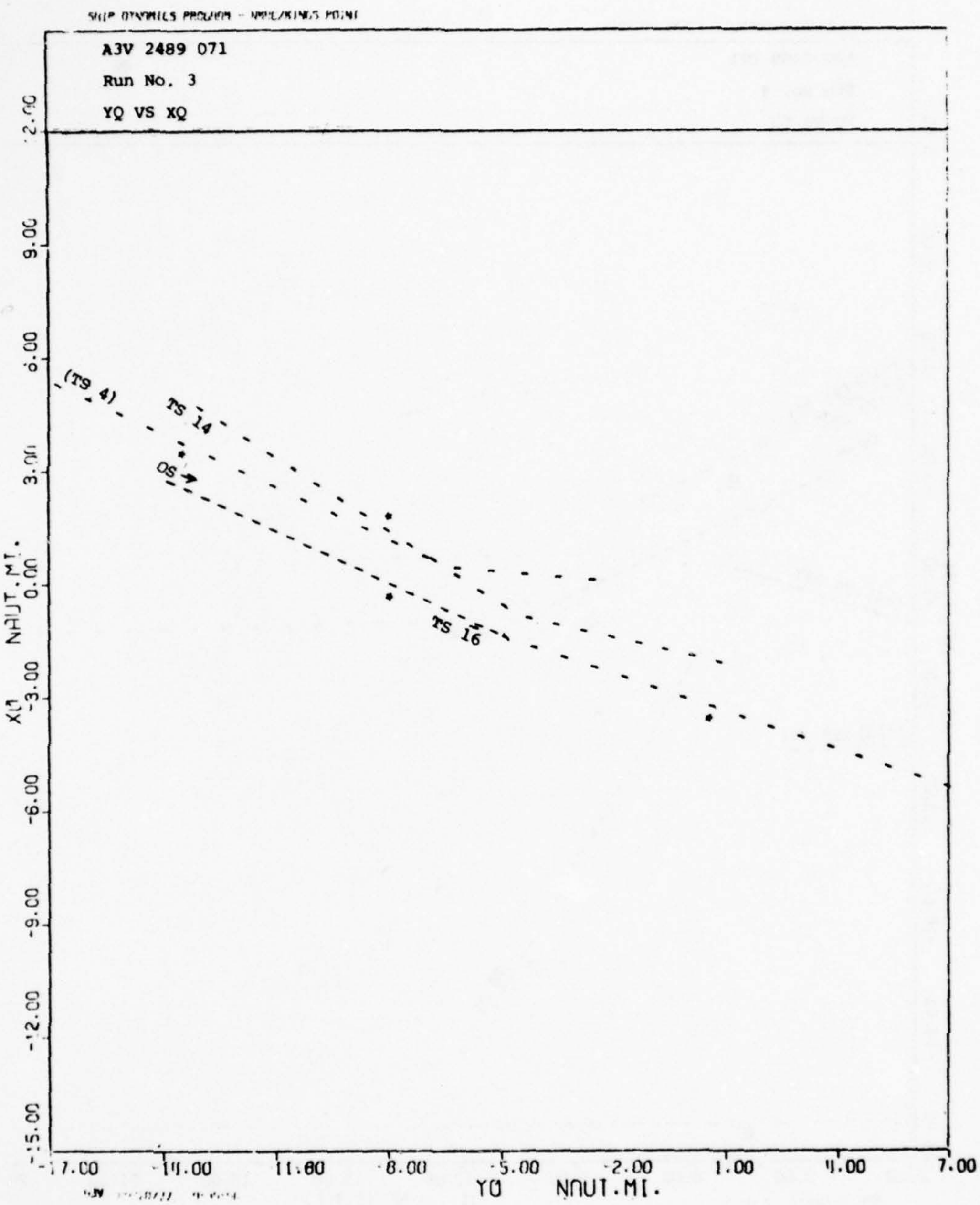
B3C 2491 070
Run No. 3
YQ VS XQ
TS 20
TS 39
TS 25
(+10) (TS 40)
TS 15
TS 12
TS 7
OS
XO NAUT.MI.
YO NAUT.MI.
56.50
54.50
52.50
50.50
48.50
46.50
44.50
42.50
40.50
38.50
3.00
5.00
7.00
9.00
11.00
13.00
15.00
17.00
19.CC


B4C 2491 070
Run No. 4
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
TS 38
TS 29
TS 17
(+1)
(+2)
50.00
52.00
54.00
56.00
58.00
60.00
62.00
64.00
66.00
68.00
15.00
17.00
19.00
21.00
23.00
25.00
27.00
29.00
31.00

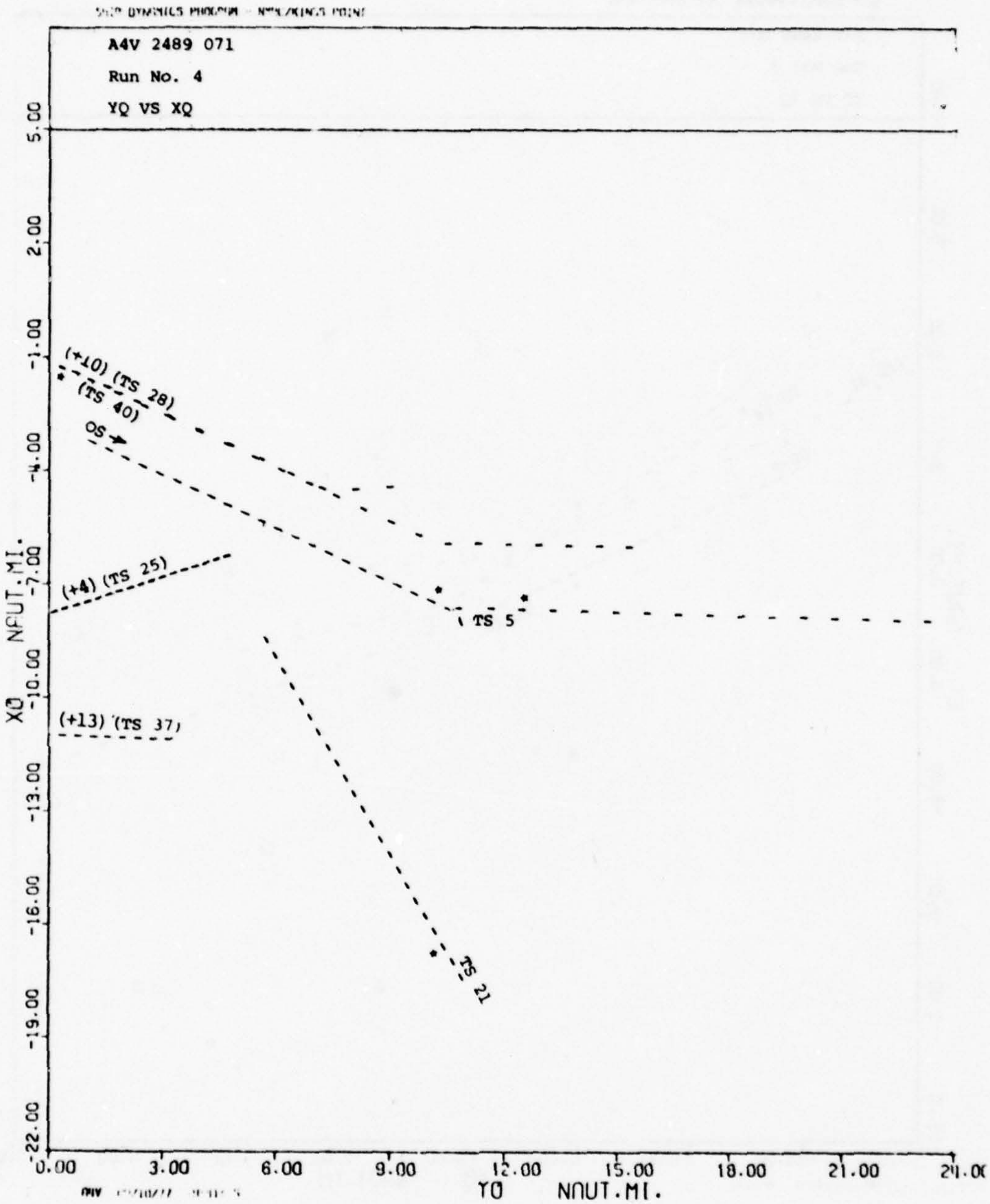

AlV 2489 071
Run No. 1
YQ VS XQ
OS
(+4) (TS 15)
TS 3
XQ NAUT.MI.
YQ NAUT.MI.
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
31.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
-15.00



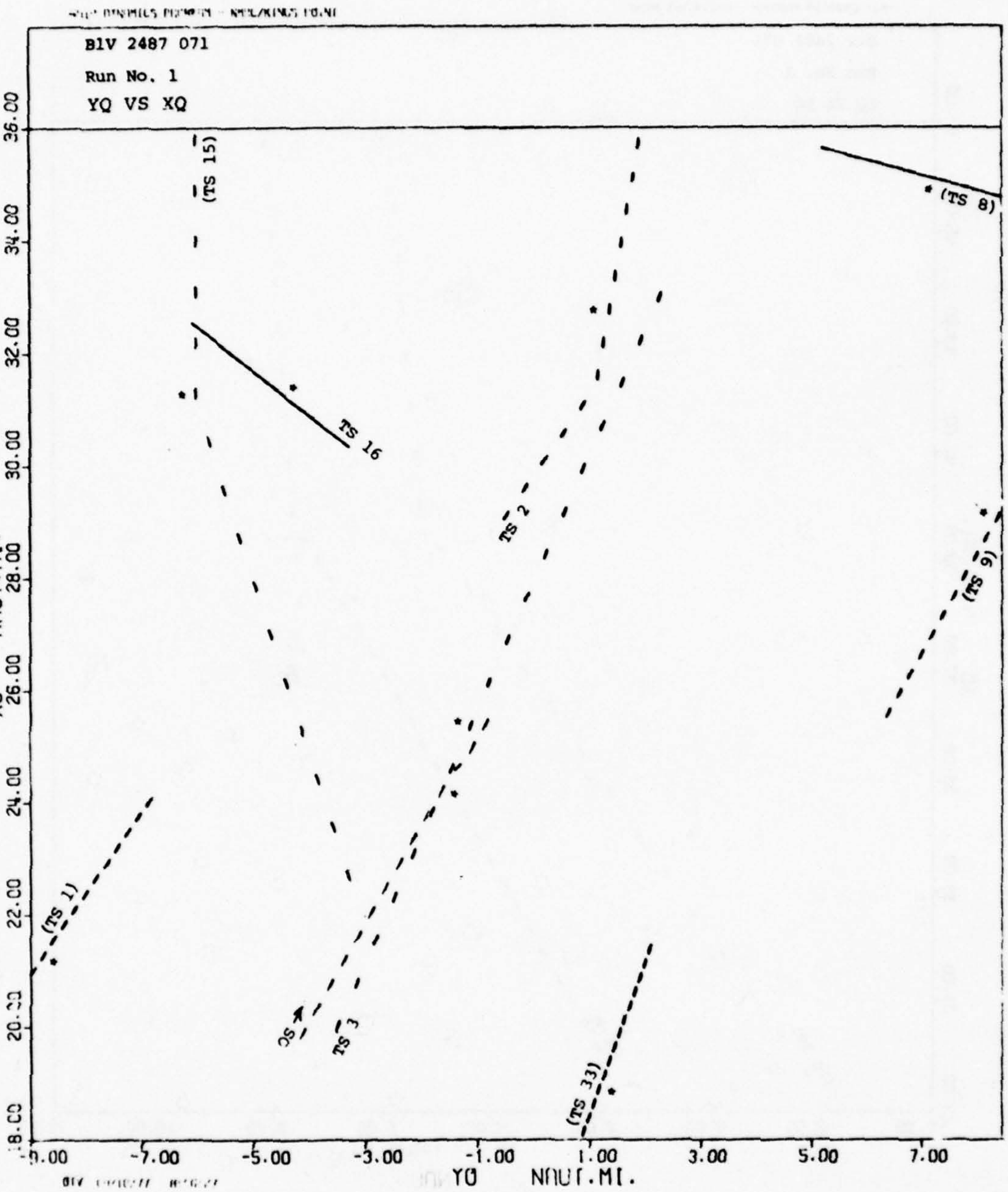
A2V 2489 071
Run No. 5
YQ VS XQ
TS 27
TS 7
TS 9
TS 8
TS 1
OS
TS 39
(+5) (TS 19)
TS 13
TS 2
XQ NAUT.MI.
YQ NAUT.MI.



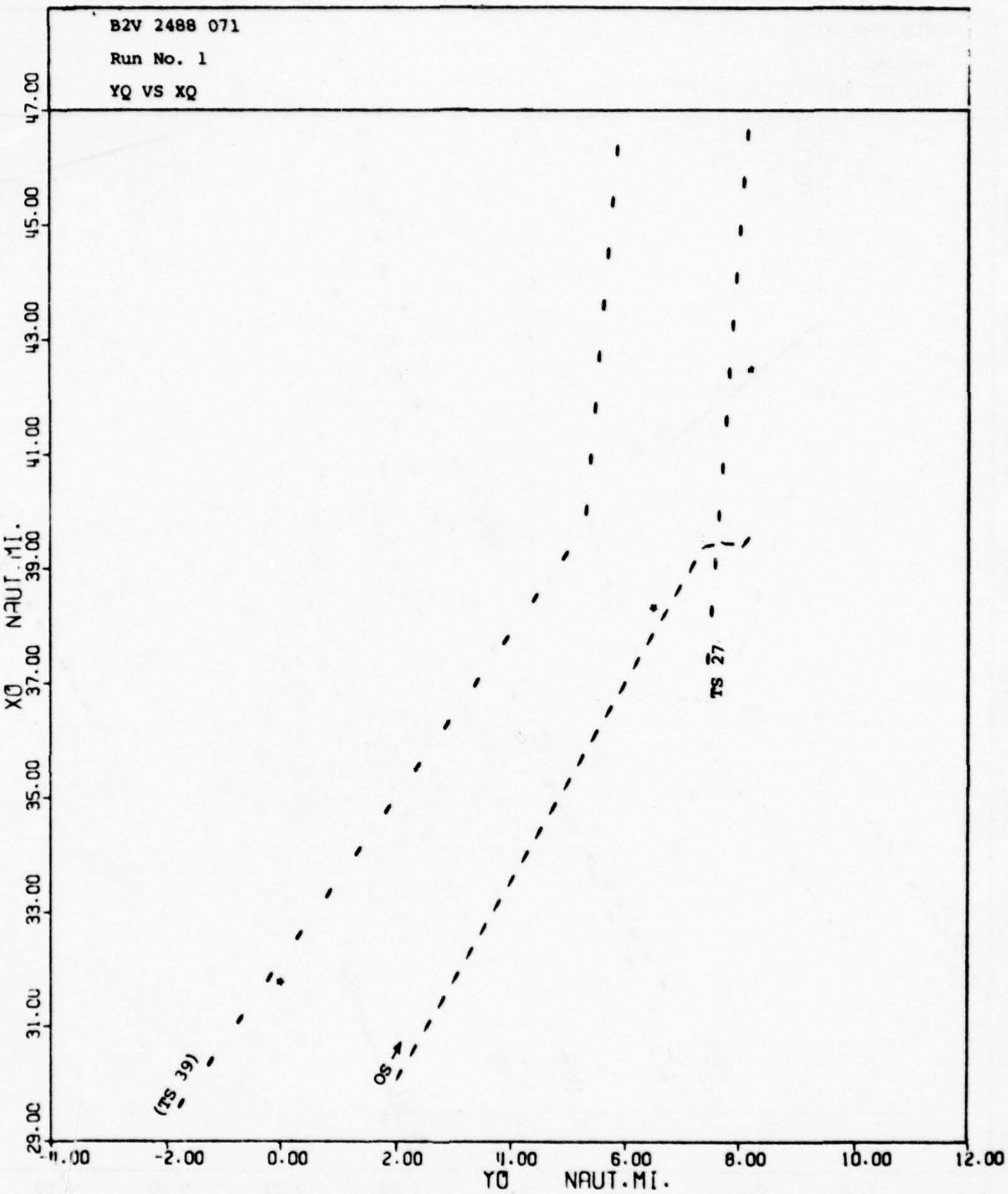
A3V 2489 071
Run No. 3
YQ VS XQ
(TS 4)
TS 14
OS
TS 16
XQ NAUT.MI.
YQ NAUT.MI.
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-15.00
-17.00
7.00

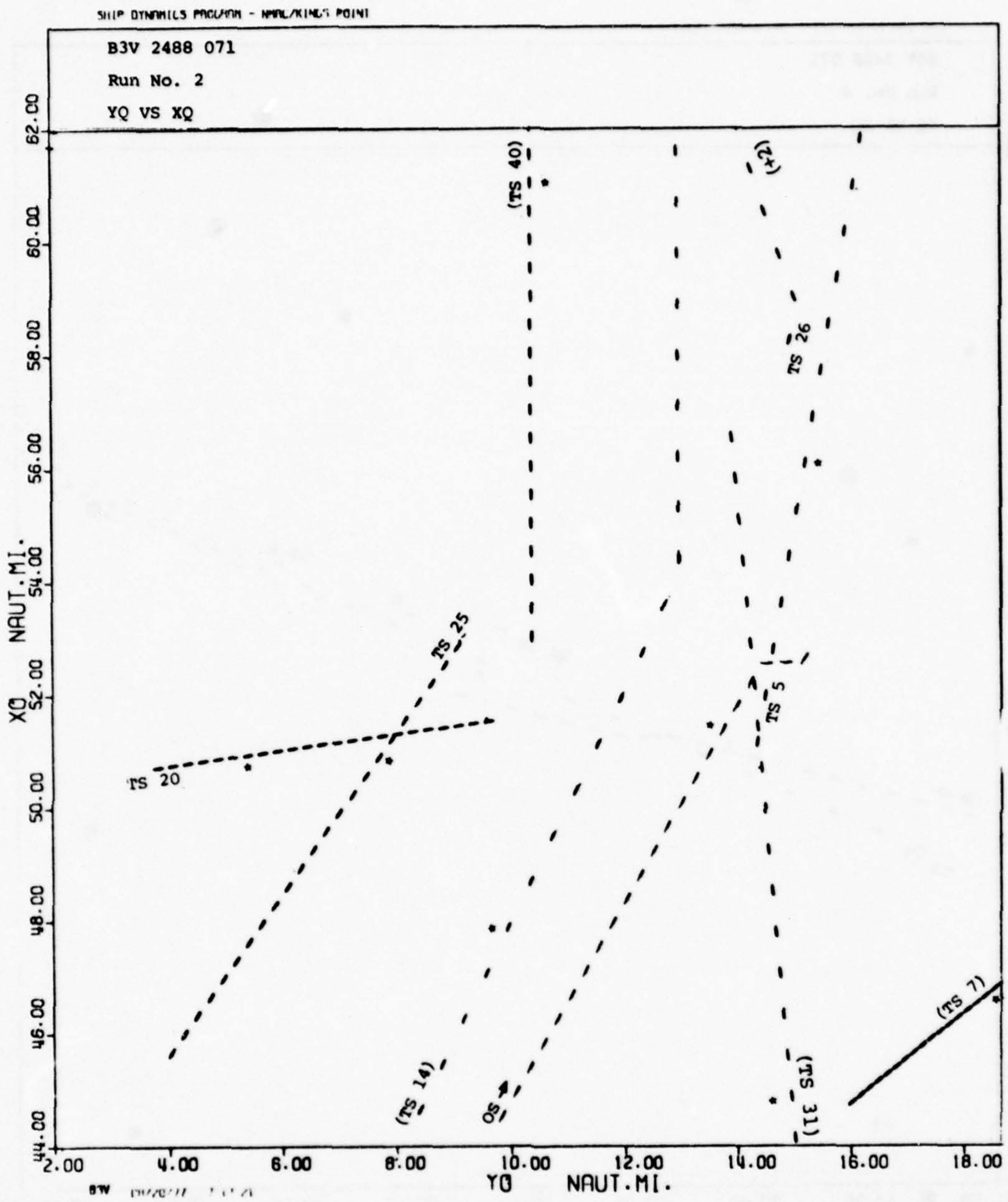


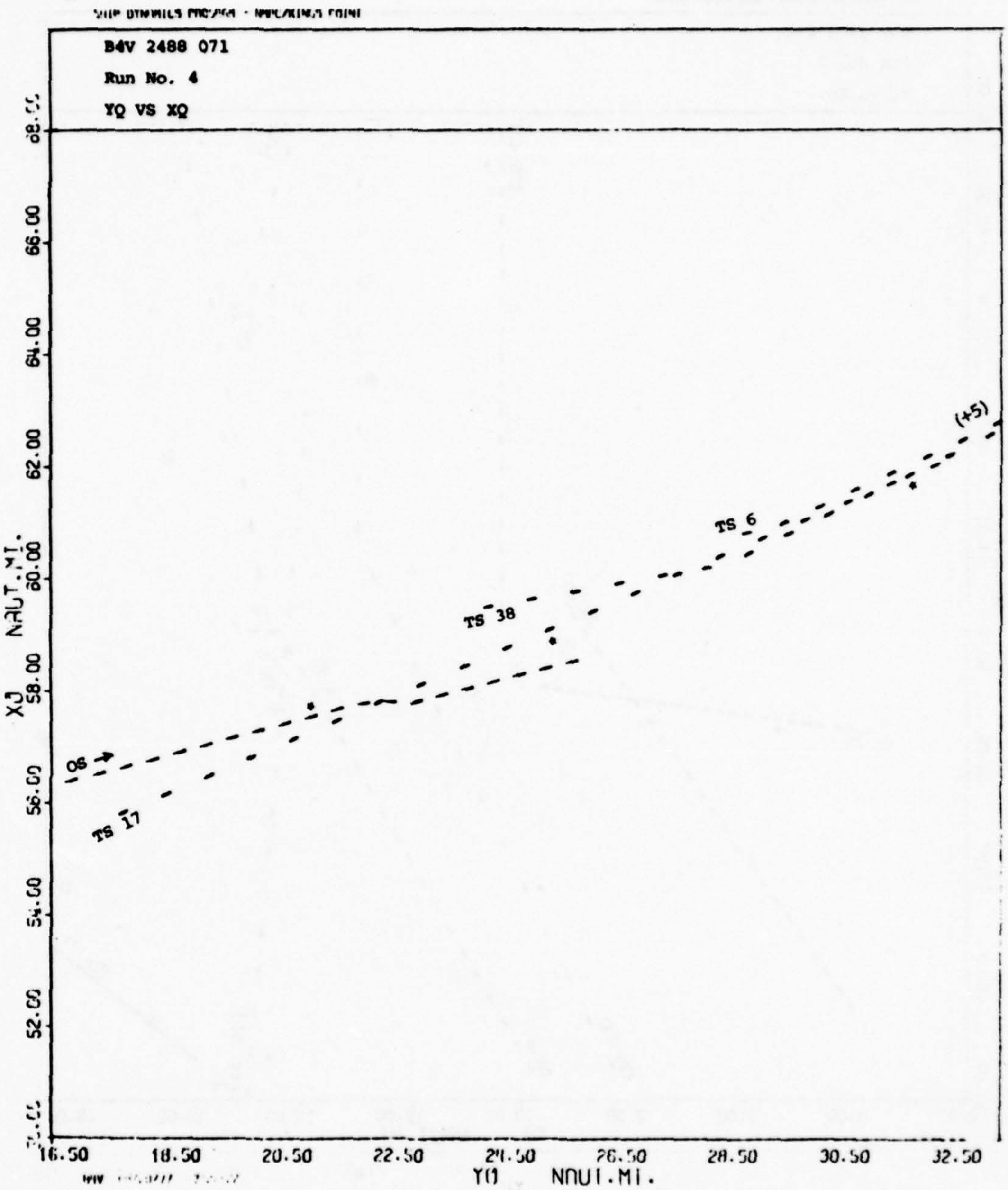
A4V 2489 071
Run No. 4
YQ VS XQ
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
XQ NAUT.MI.
(+10) (TS 28)
(TS 40)
OS
(+4) (TS 25)
TS 5
(+13) (TS 37)
TS 21
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
YQ NAUT.MI.

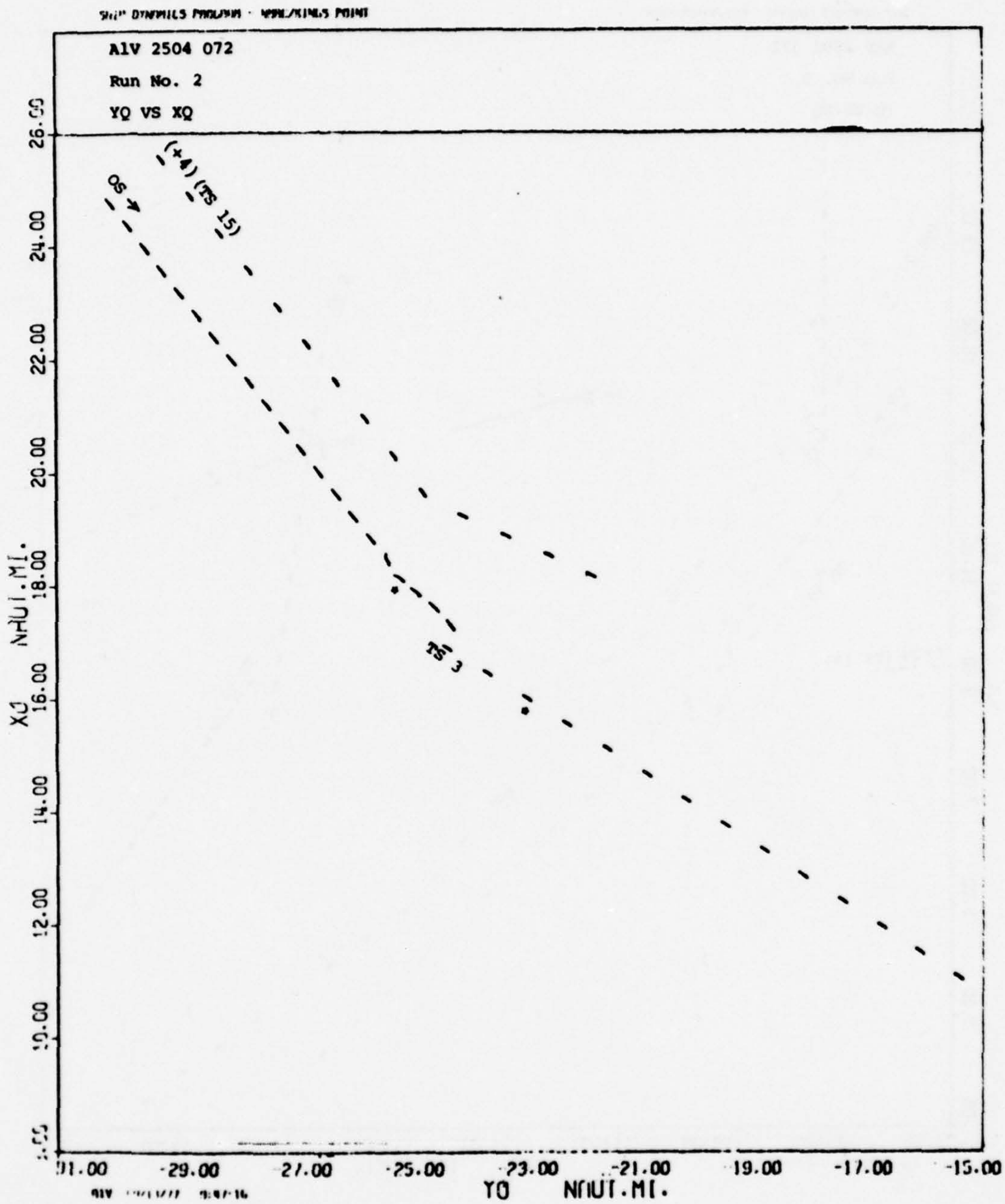

B1V 2487 071
Run No. 1
YQ VS XQ
(TS 15)
(TS 8)
TS 16
TS 2
(TS 9)
(TS 1)
TS 3
(TS 33)
XQ NAUT.MI.
YQ NAUT.MI.
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
-9.00
-7.00
-5.00
-3.00
-1.00
1.00
3.00
5.00
7.00

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT

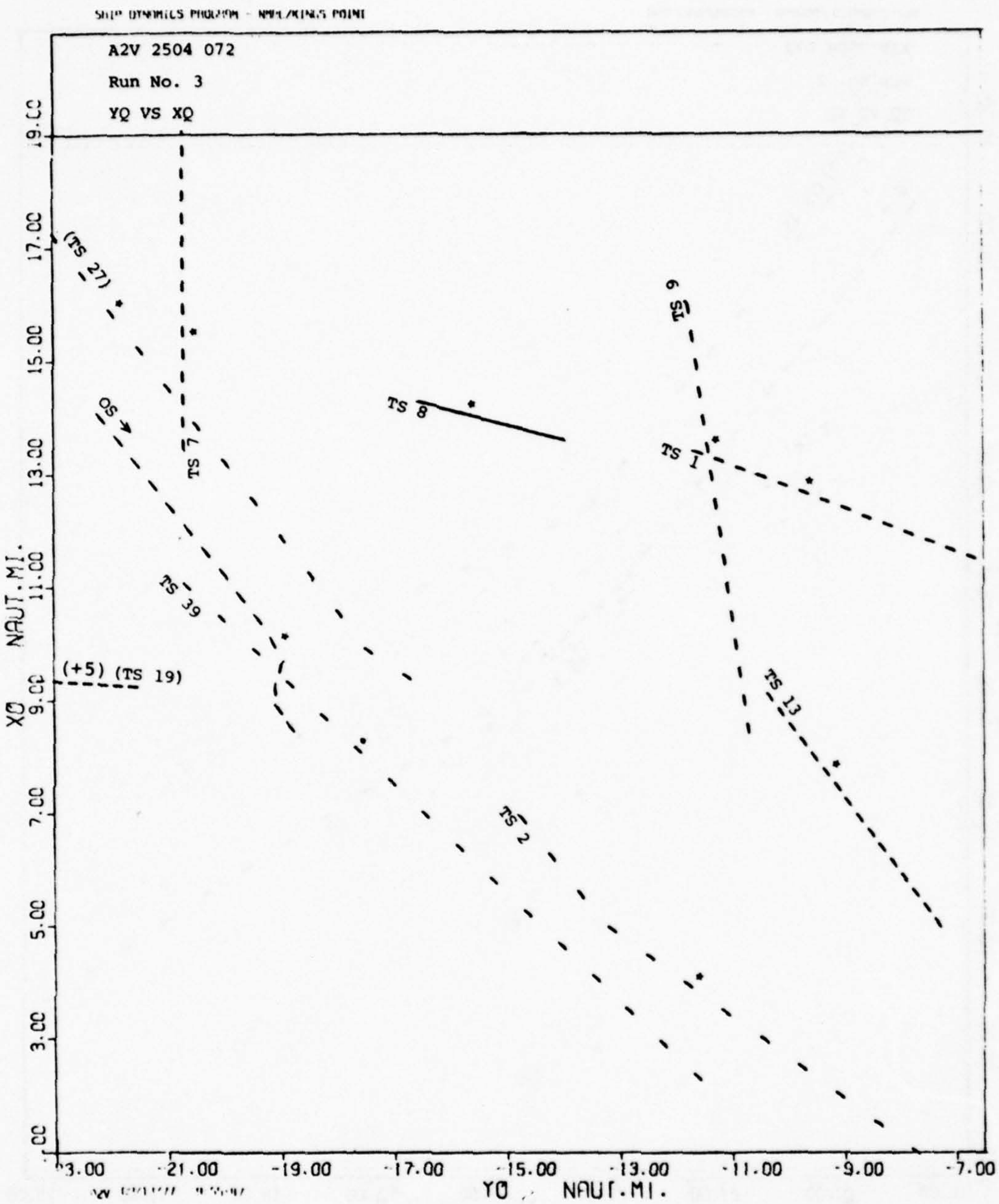



SHIP DYNAMICS PROGRAM - NMRL/KINGS POINT
B3V 2488 071
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
TS 20
TS 25
(TS 40)
(+2)
TS 26
TS 5
(TS 14)
OS
(TS 31)
(TS 7)
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
44.00
46.00
48.00
50.00
52.00
54.00
56.00
58.00
60.00
62.00

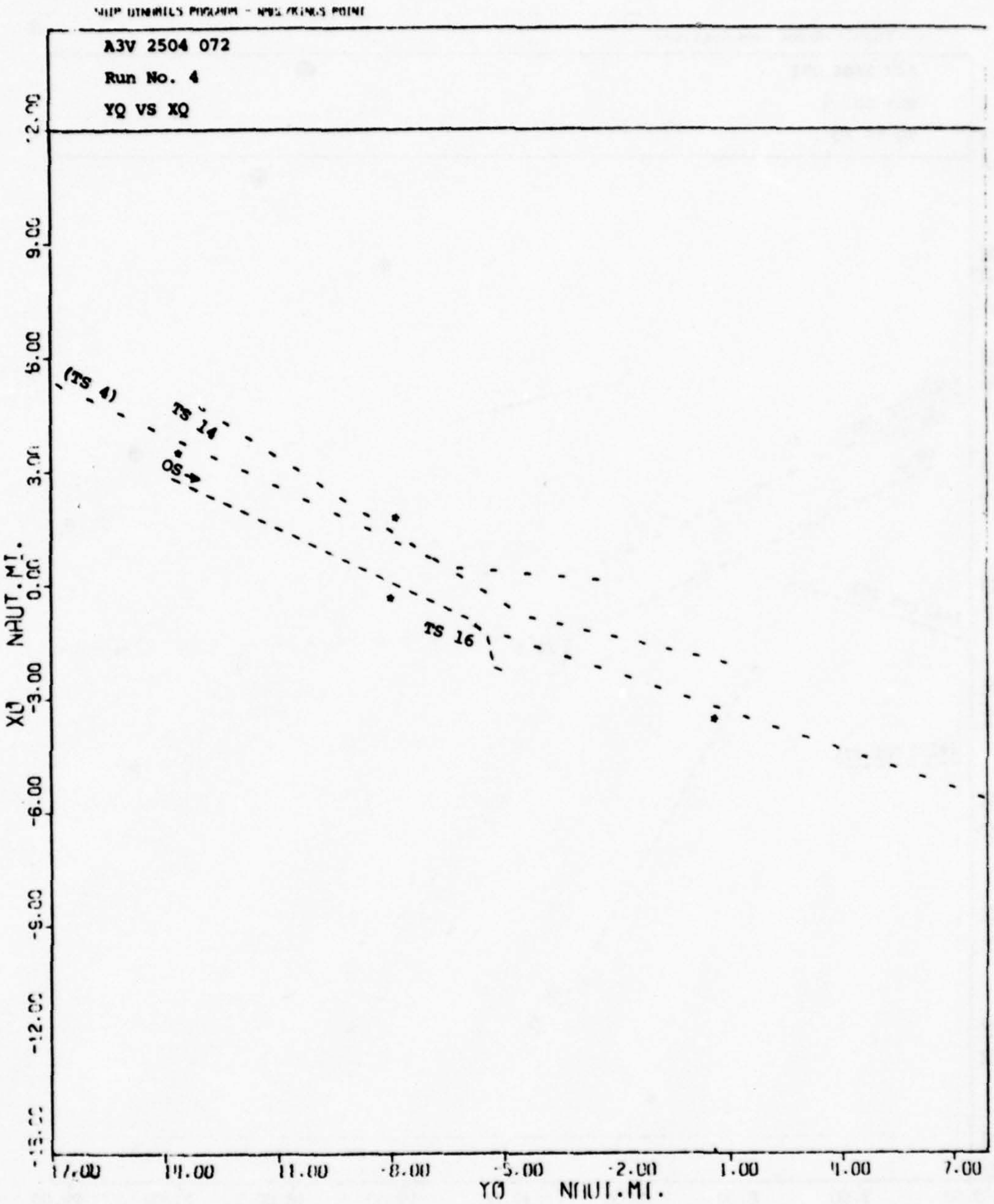

B4V 2488 071
Run No. 4
YQ VS XQ
OS
TS 17
TS 38
TS 6
(+5)
66.00
64.00
62.00
60.00
58.00
56.00
54.00
52.00
16.50
18.50
20.50
22.50
28.50
30.50
32.50
NAUT.MI.



A1V 2504 072
Run No. 2
YO VS XO
OS
(+4) (TS 15)
TS 3
XO NAUT.MI.
YO NAUT.MI.
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
-29.00
-27.00
-25.00
-23.00
-21.00
-19.00
-17.00
-15.00

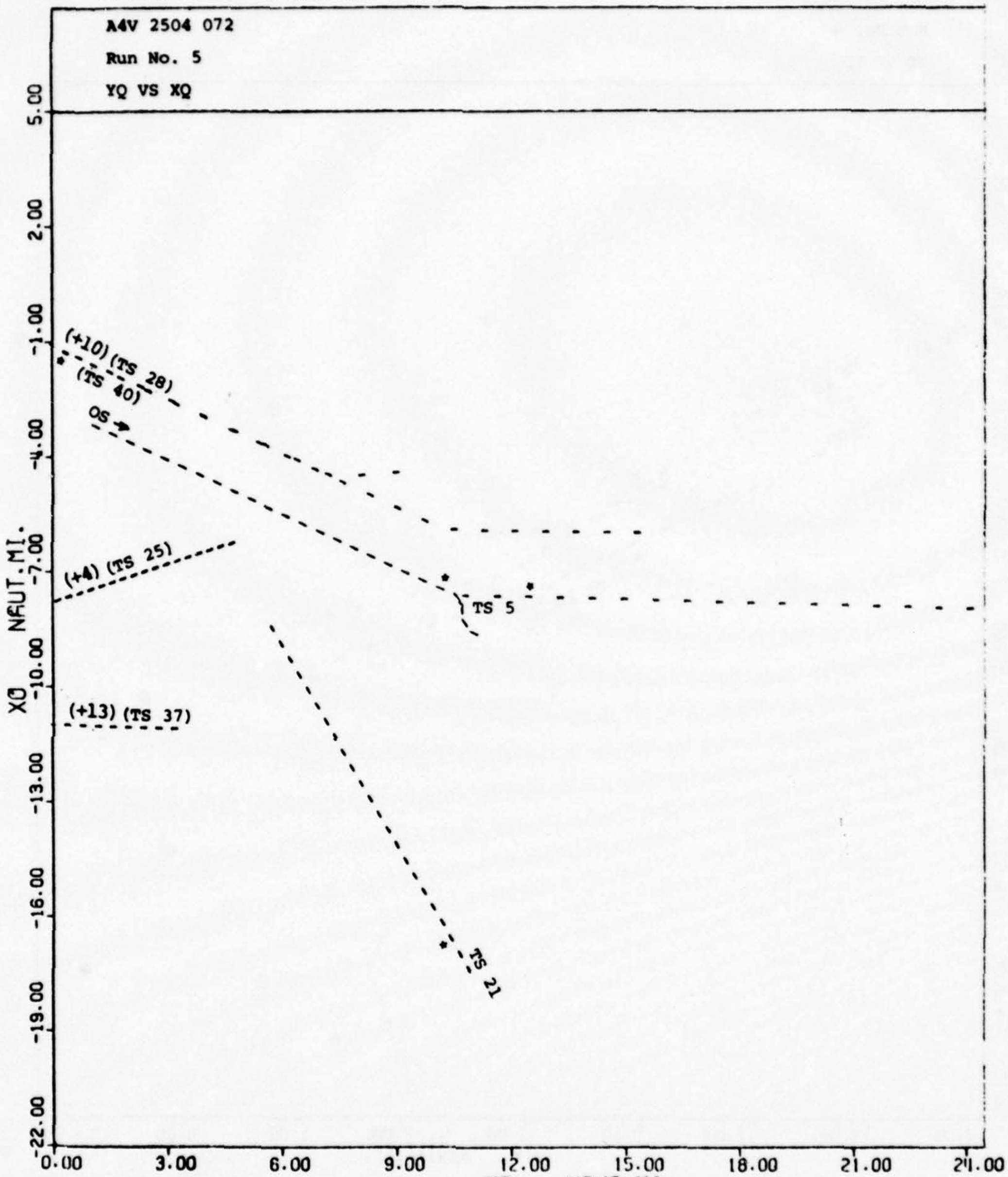


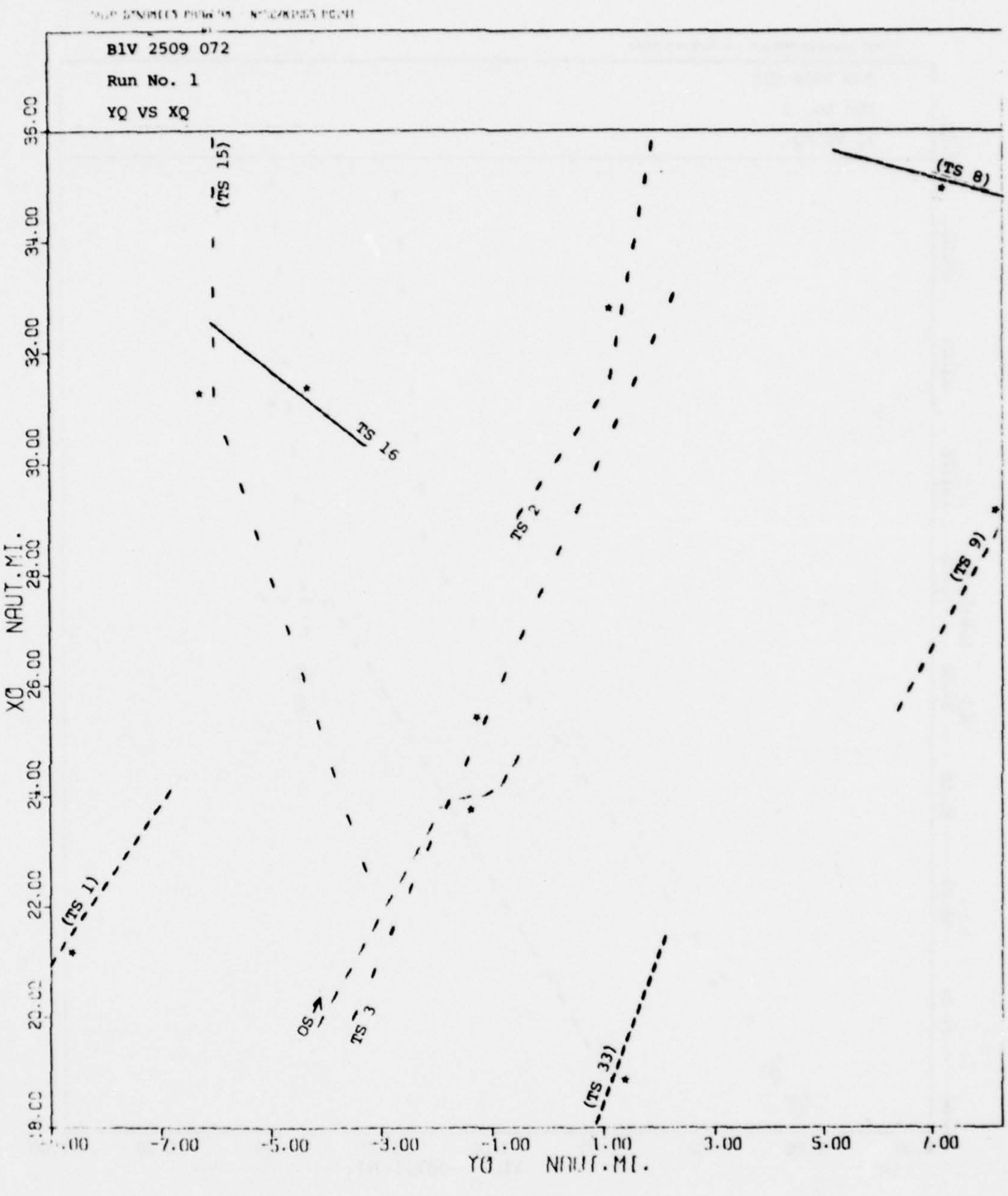
SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A2V 2504 072
Run No. 3
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
(TS 27)
TS 7
TS 9
OS
TS 8
TS 1
TS 39
(+5) (TS 19)
TS 13
TS 2
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
-23.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00

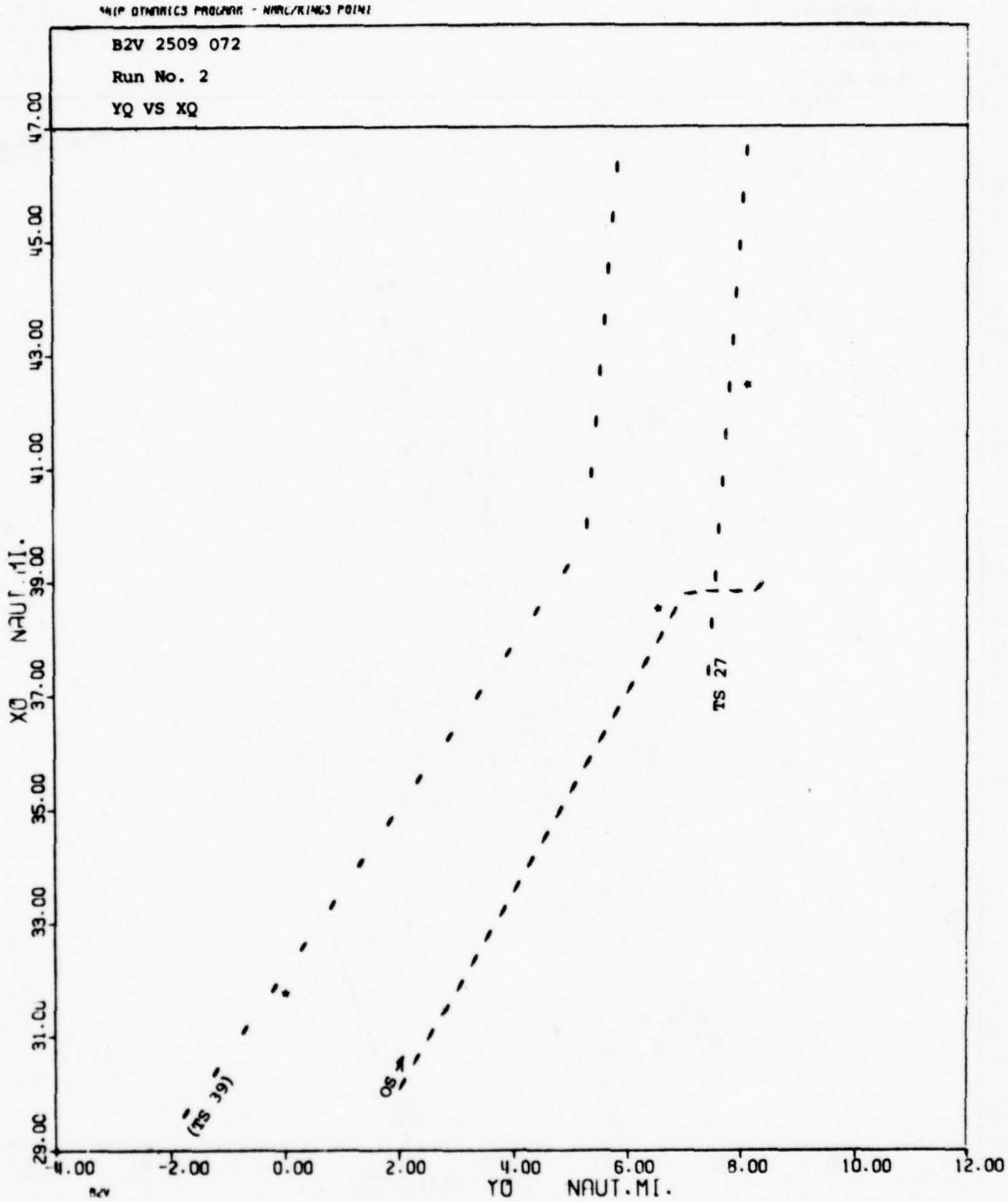


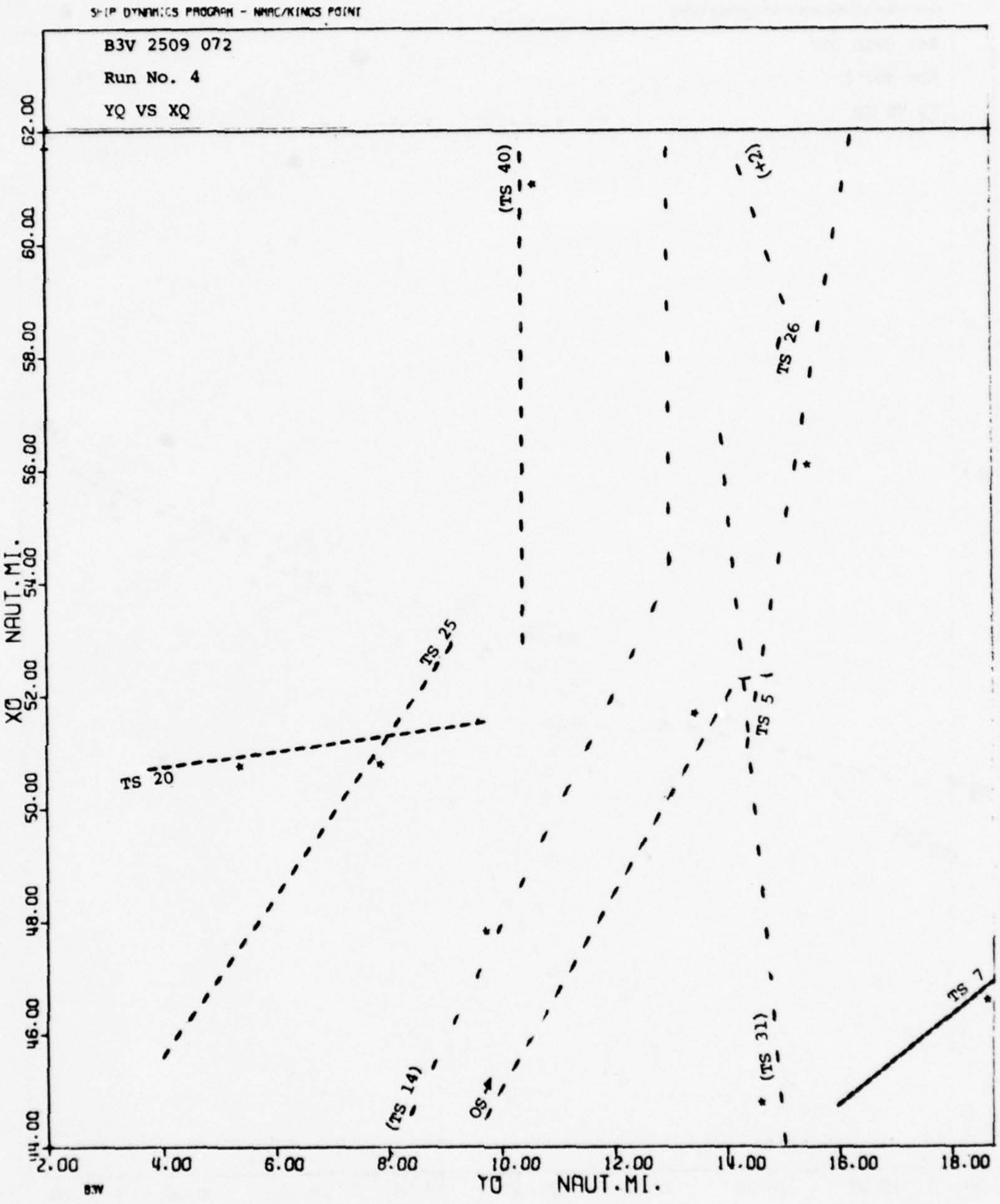
SHIP DYNAMICS PROGRAM - NMS/KINGS POINT
A3V 2504 072
Run No. 4
YQ VS XQ
(TS 4)
TS 14
OS
TS 16
XQ NAUT.MI.
YQ NAUT.MI.

SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT

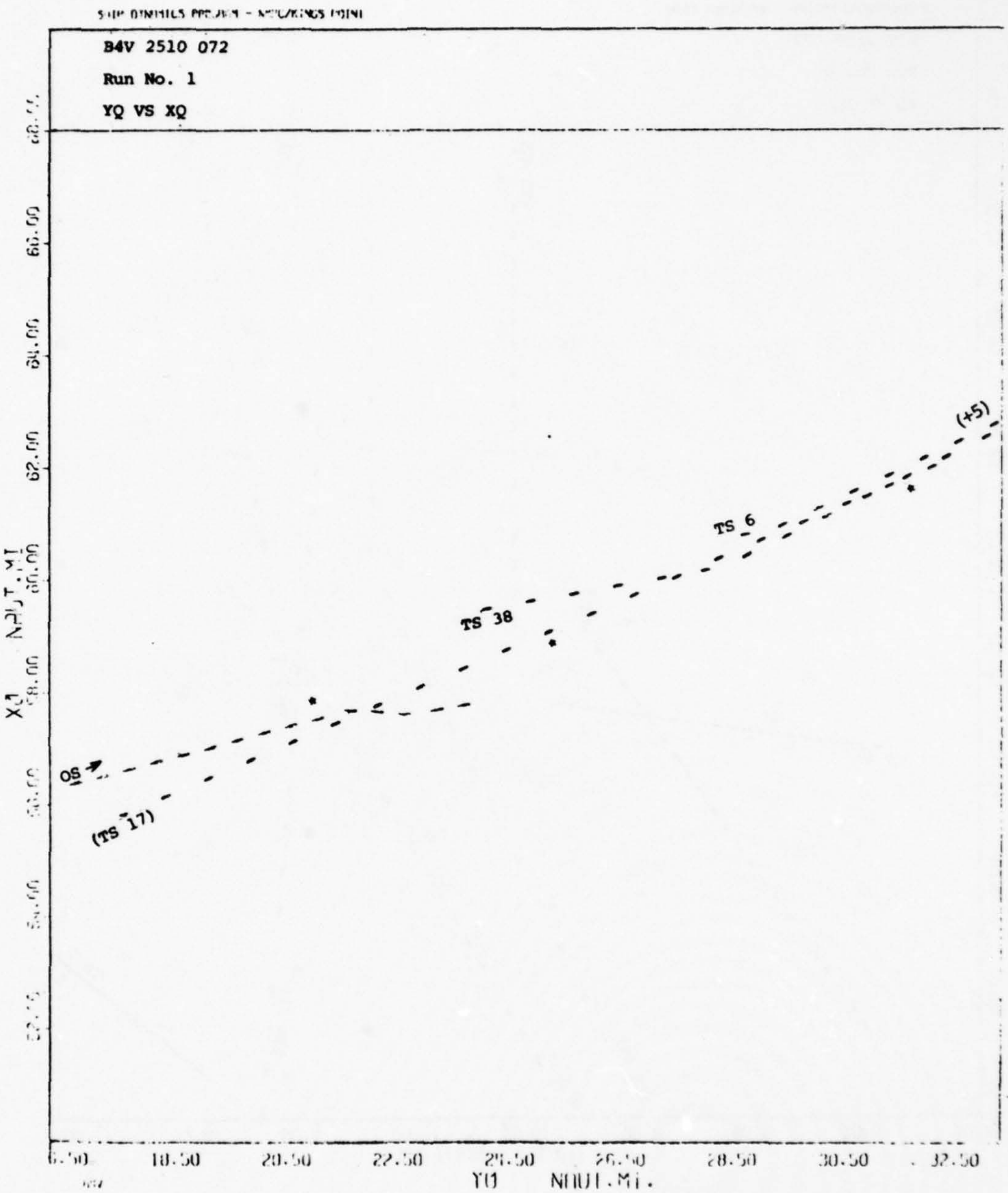


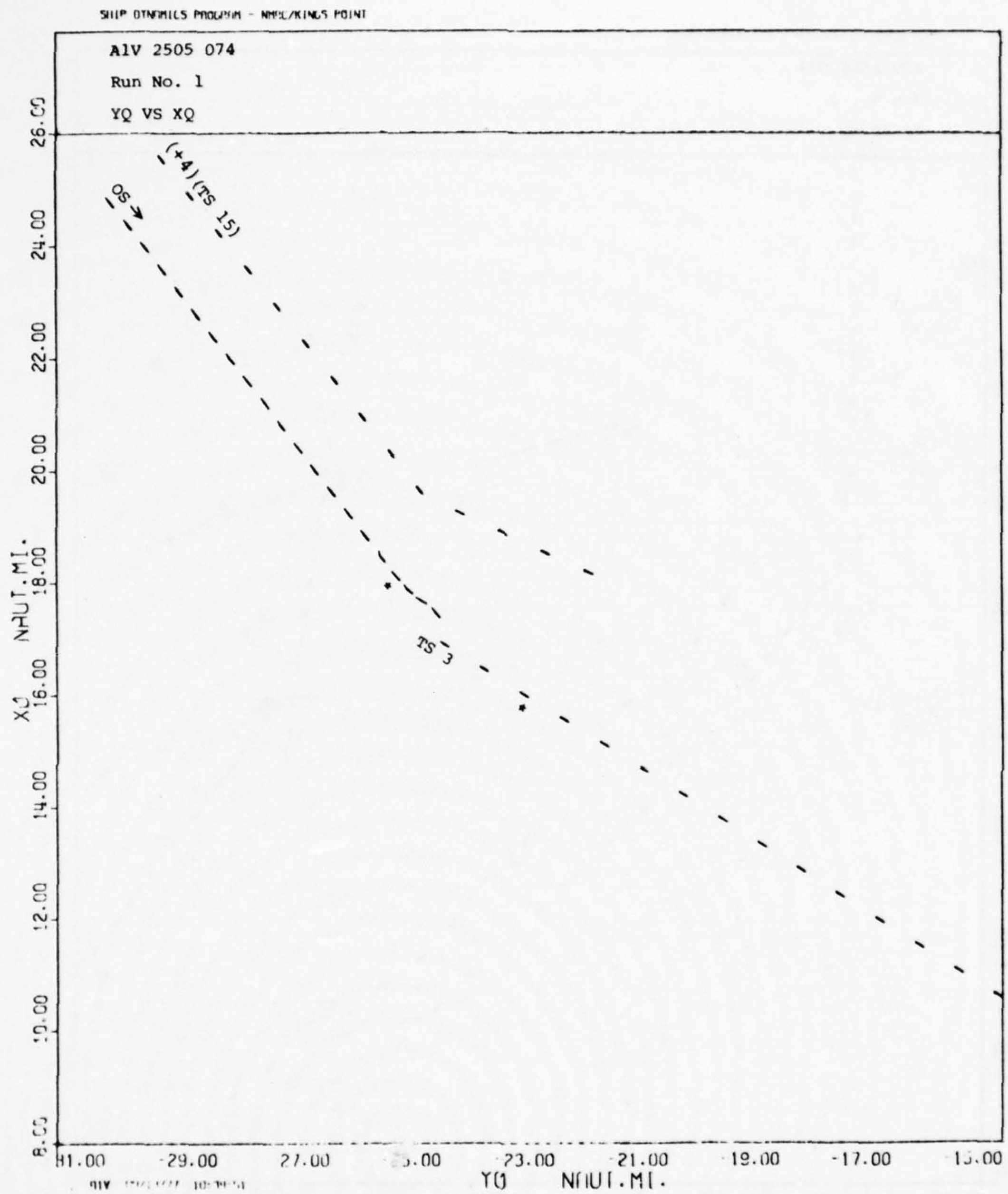

B1V 2509 072
Run No. 1
YQ VS XQ
(TS 15)
(TS 8)
TS 16
TS 2
(TS 9)
(TS 1)
OS
TS 3
(TS 33)
XQ NAUT.MI.
YQ NAUT.MI.


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B2V 2509 072
Run No. 2
YQ VS XQ
XO NAUT.MI.
47.00
45.00
43.00
41.00
39.00
37.00
35.00
33.00
31.00
29.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
YO NAUT.MI.
(TS 39)
OS
TS 27
B2V

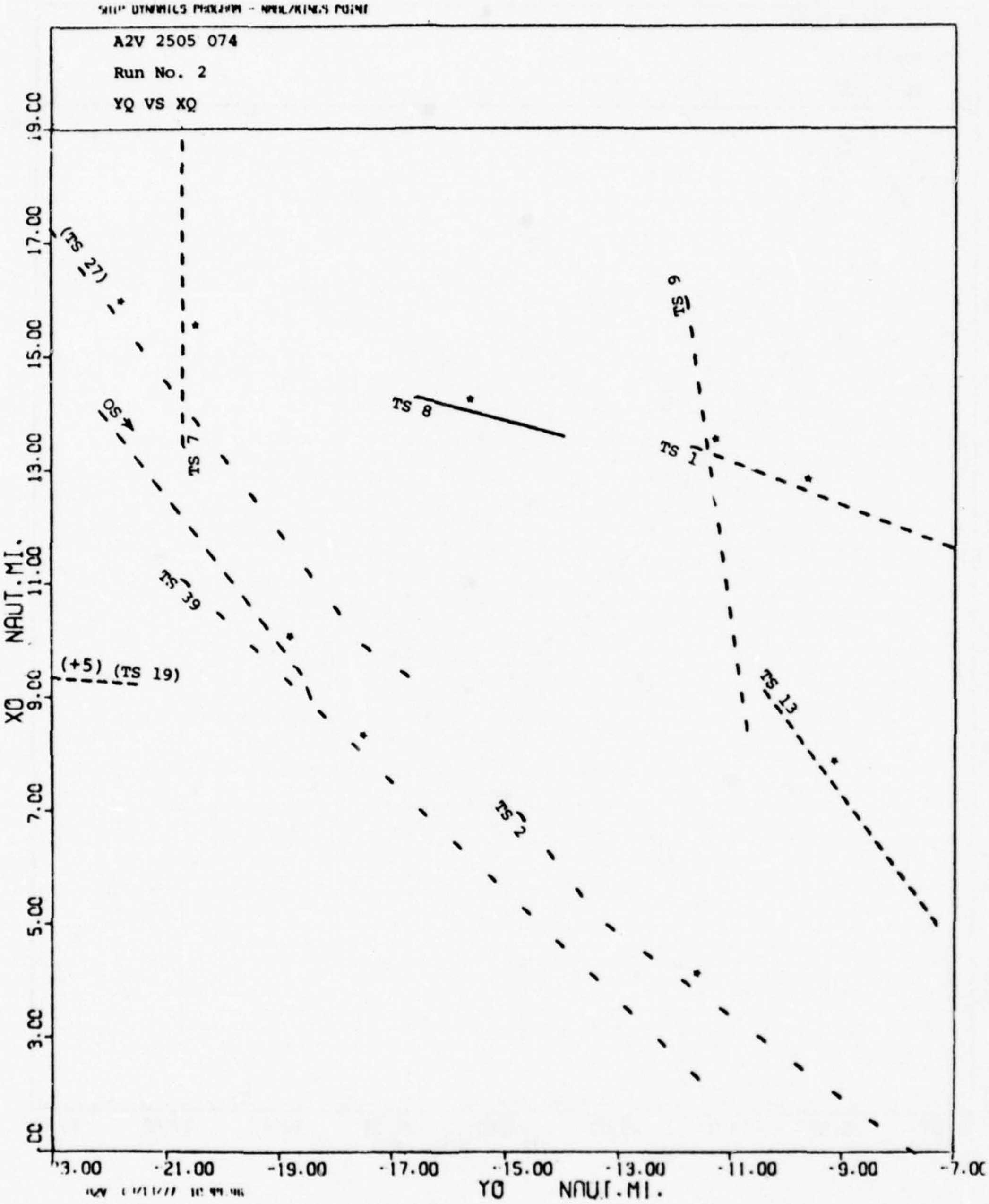


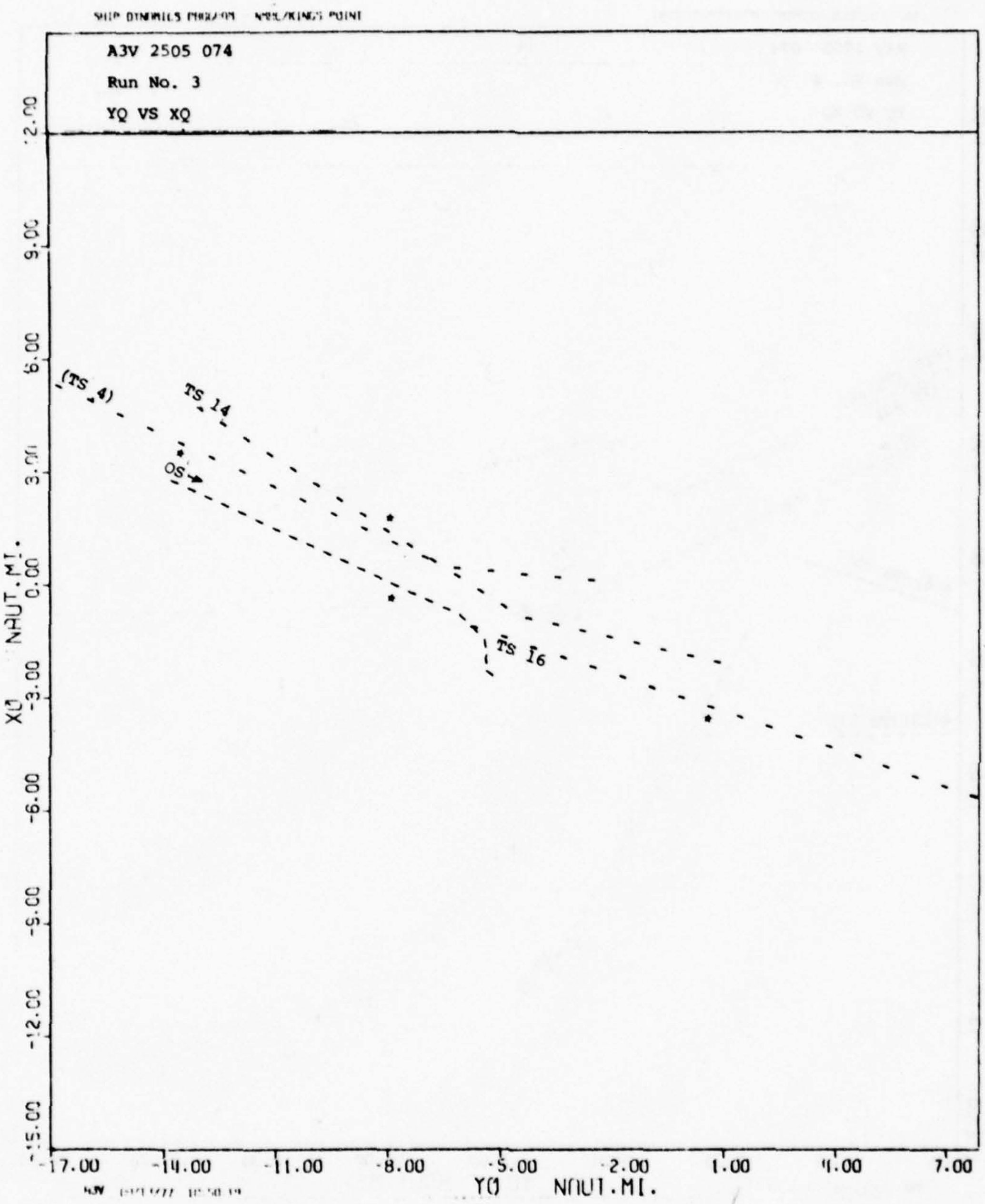
SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B3V 2509 072
Run No. 4
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
62.00
60.00
58.00
56.00
54.00
52.00
50.00
48.00
46.00
44.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
(TS 40)
(x2)
TS 26
TS 25
TS 20
TS 5
(TS 14)
OS
(TS 31)
TS 7
B3V


B4V 2510 072
Run No. 1
YQ VS XQ
OS
(TS 17)
TS 38
TS 6
(+5)
XQ NAUT.MI
YQ NAUT.MI.
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
60.00
62.00
64.00
66.00

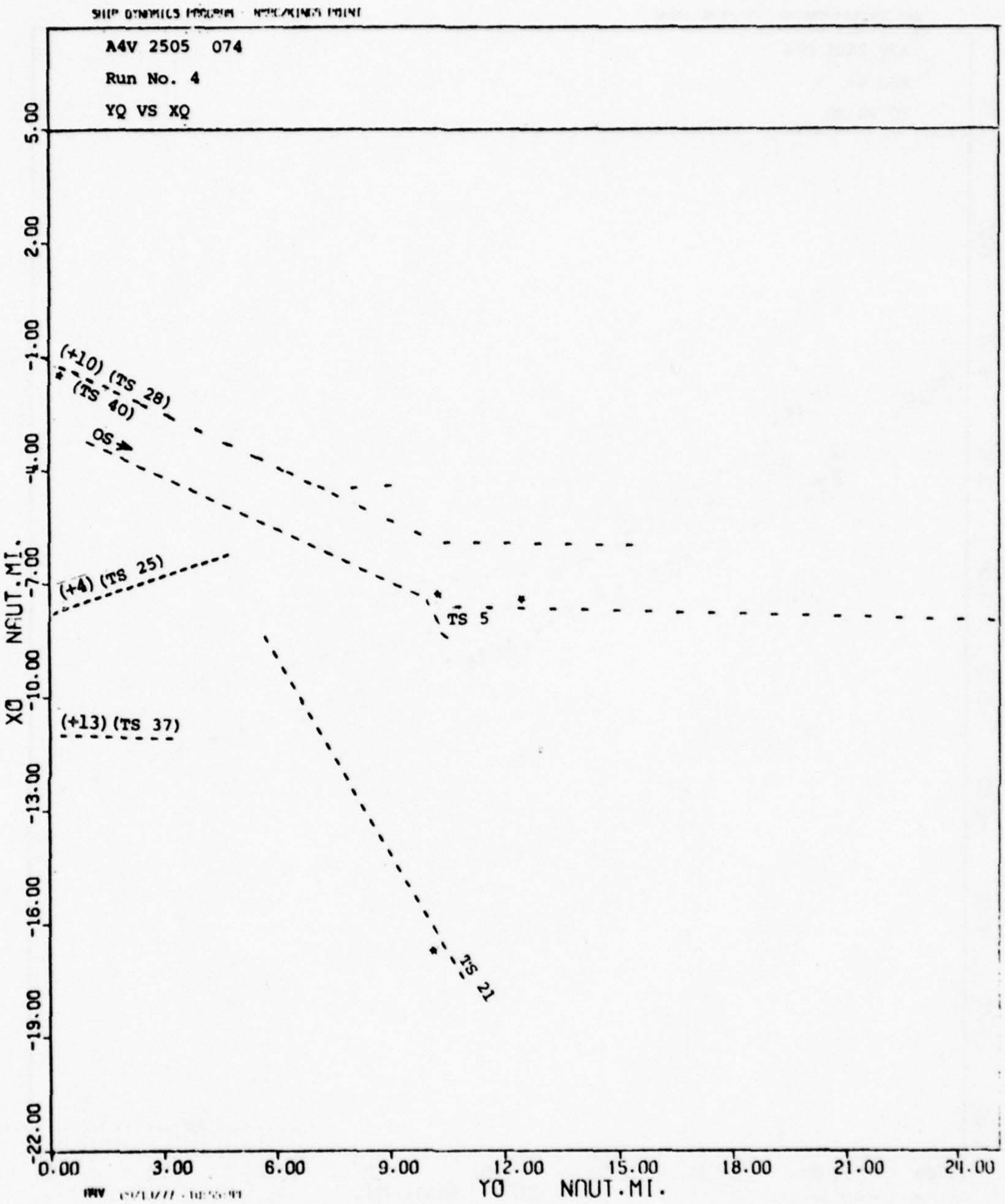


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
A1V 2505 074
Run No. 1
YQ VS XQ
OS
(+4)(TS 15)
TS 3
XQ NAUT.MI.
YQ NAUT.MI.
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
-31.00
-29.00
-27.00
-23.00
-21.00
-19.00
-17.00

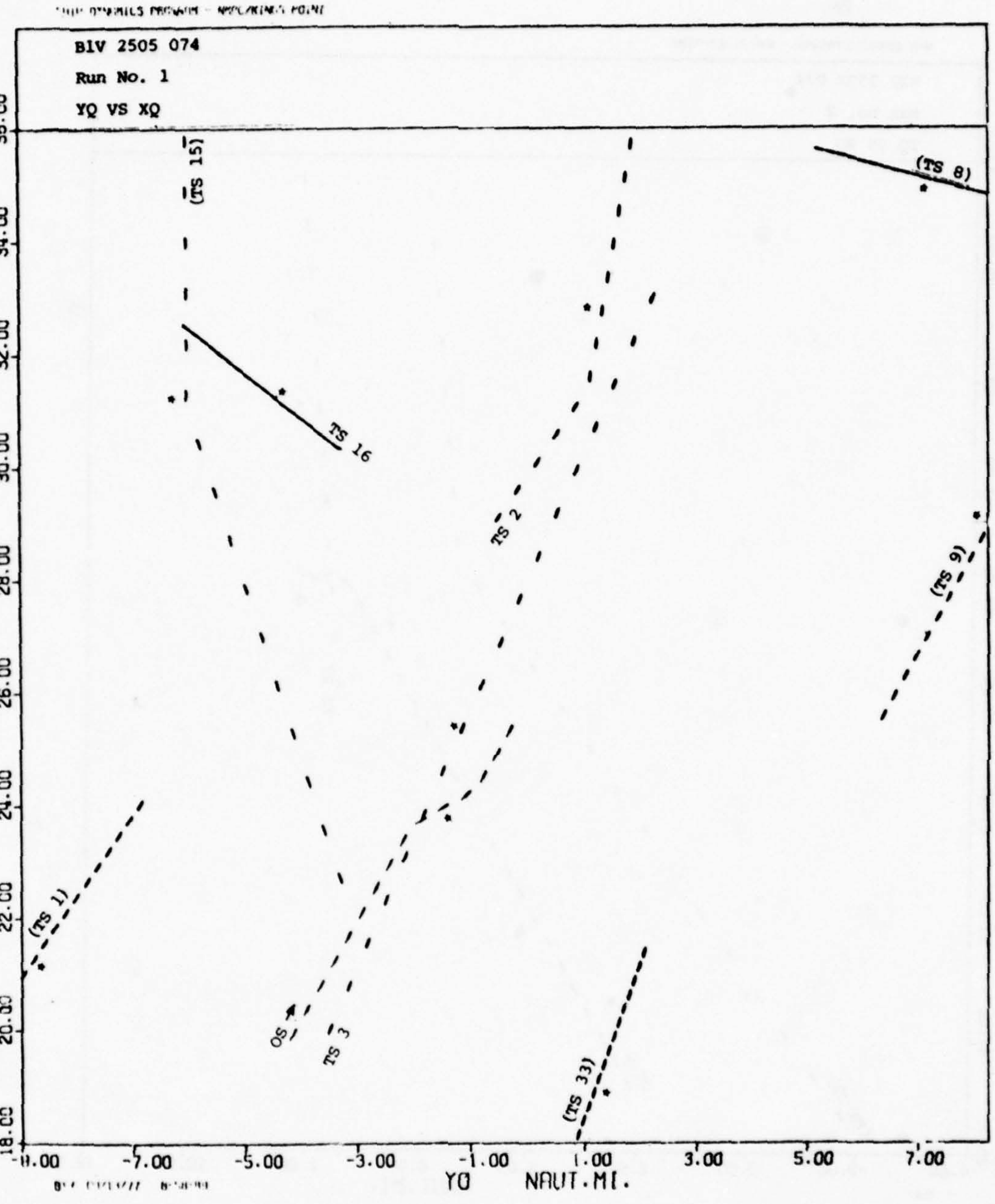

A2V 2505 074
Run No. 2
YQ VS XQ
XO NAUT.MI.
YO NAUT.MI.
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
-21.00
-19.00
-17.00
-15.00
-13.00
-11.00
-9.00
-7.00
(TS 27)
TS 7
TS 8
TS 9
TS 1
OS
TS 39
(+5) (TS 19)
TS 13
TS 2

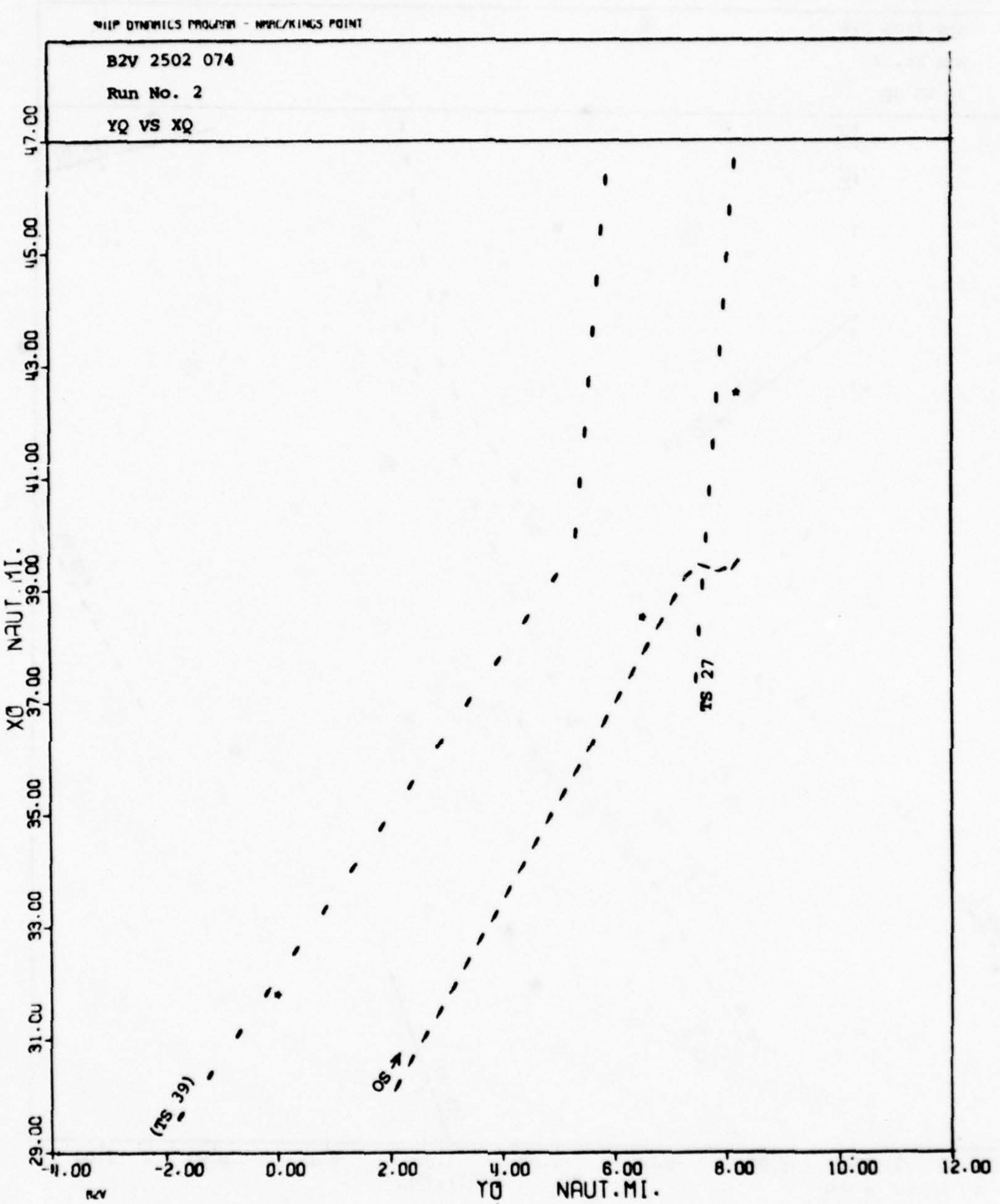


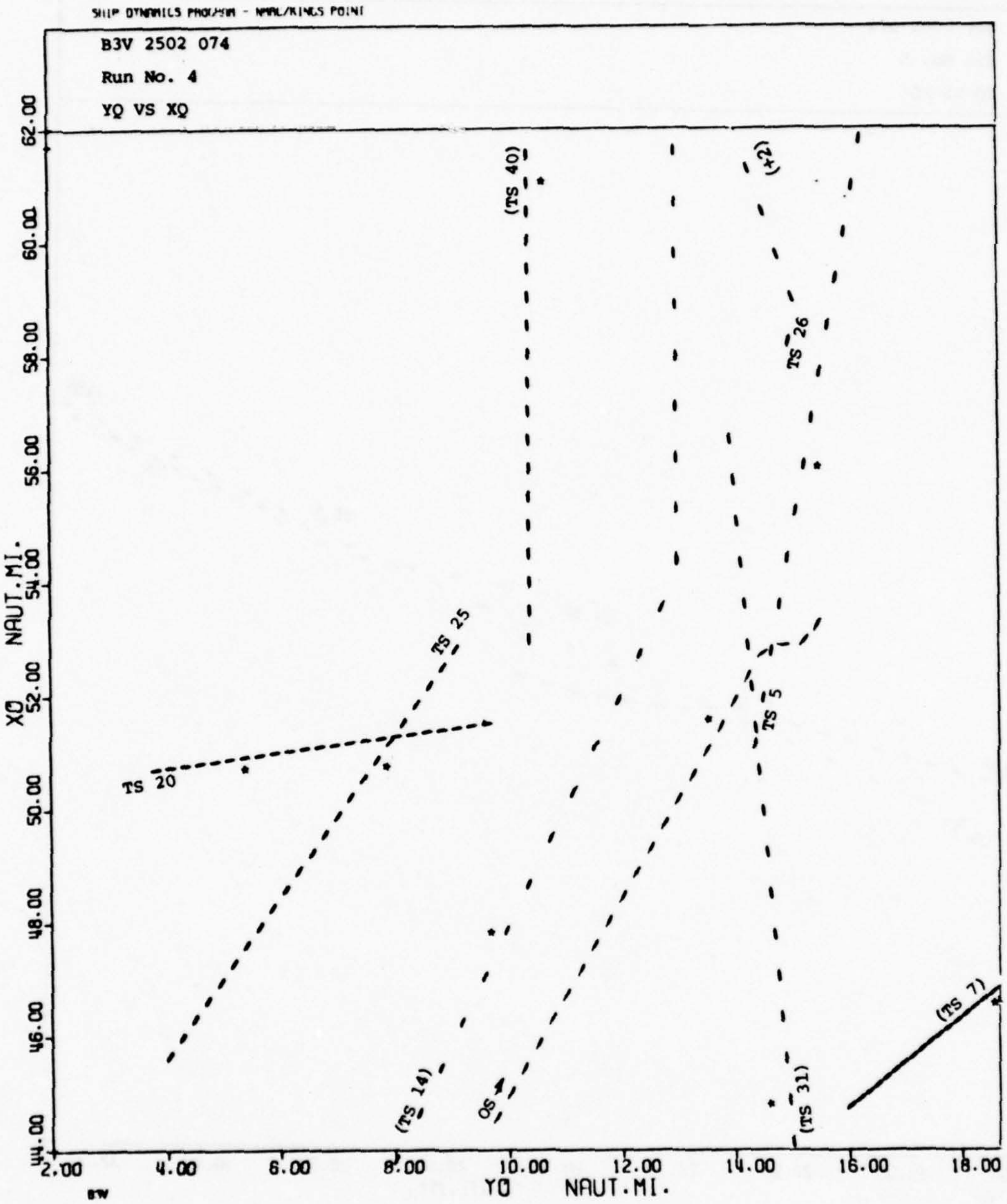
SHIP DYNAMICS PROGRAM NMRL/KINGS POINT
A3V 2505 074
Run No. 3
YQ VS XQ
(TS 4)
TS 14
OS
TS I6
XQ NAUT.MI.
YQ NAUT.MI.

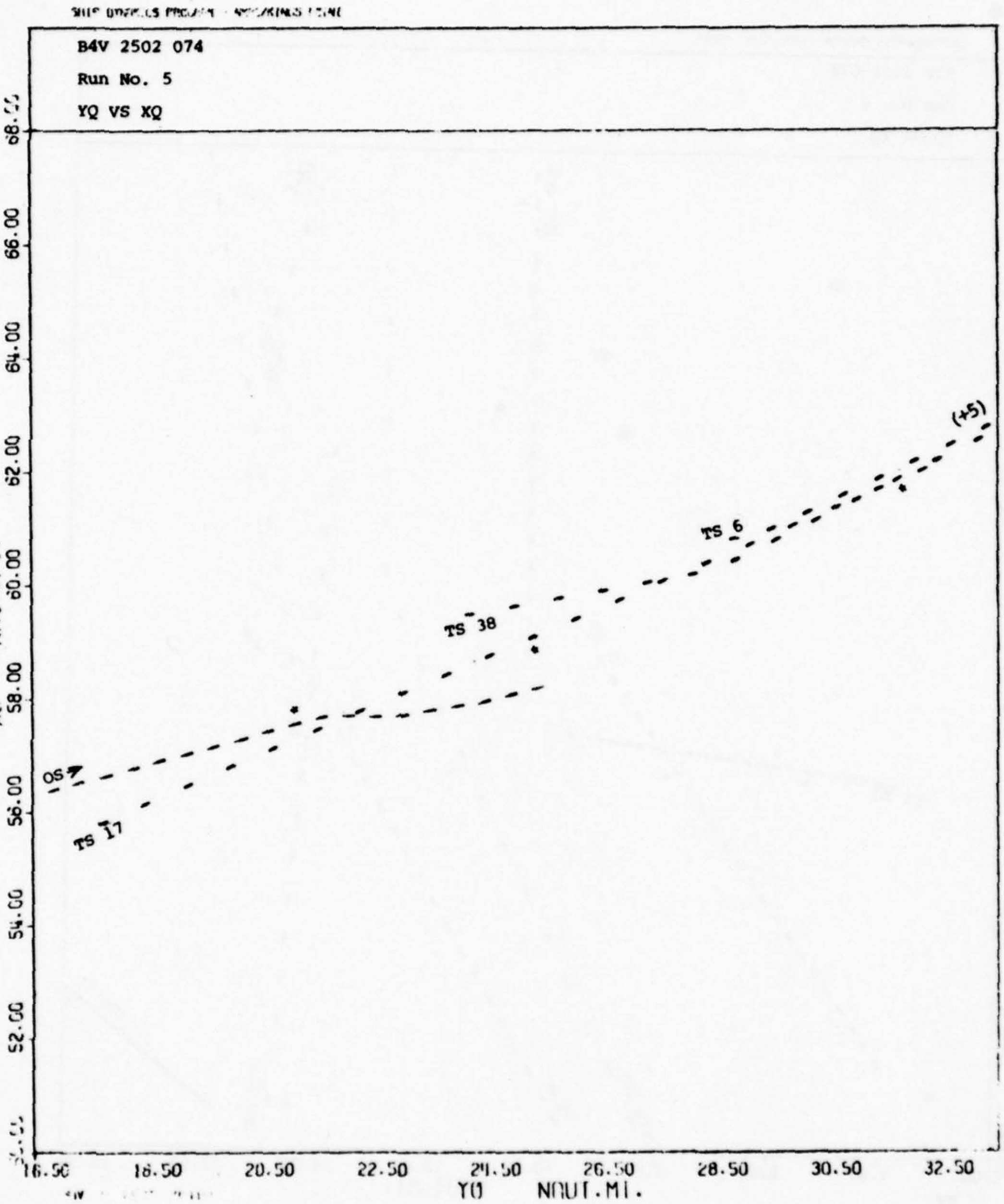


A4V 2505 074
Run No. 4
YQ VS XQ
5.00
2.00
-1.00
-4.00
-7.00
-10.00
-13.00
-16.00
-19.00
-22.00
XQ NAUT.MI.
0.00
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
YO NAUT.MI.
(+10) (TS 28)
(TS 40)
OS
(+4) (TS 25)
(+13) (TS 37)
TS 5
TS 21


BIV 2505 074
Run No. 1
YQ VS XQ
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
XQ NAUT.MI.
-8.00
-7.00
-5.00
-3.00
-1.00
1.00
3.00
5.00
7.00
YQ NAUT.MI.
(TS 15)
(TS 8)
TS 16
TS 2
(TS 9)
(TS 1)
OS
TS 3
(TS 33)


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B2V 2502 074
Run No. 2
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
TS 39
OS
TS 27
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
29.00
31.00
33.00
35.00
37.00
39.00
41.00
43.00
45.00
47.00


SHIP DYNAMICS PROGRAM - NMRC/KINGS POINT
B3V 2502 074
Run No. 4
YO VS XO
XO NAUT.MI.
YO NAUT.MI.
62.00
60.00
58.00
56.00
54.00
52.00
50.00
48.00
46.00
44.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
(TS 40)
(+2)
TS 26
TS 25
TS 5
TS 20
(TS 14)
OS
(TS 31)
(TS 7)


B4V 2502 074
Run No. 5
YQ VS XQ
XQ NAUT.MI.
YQ NAUT.MI.
OS
TS 17
TS 38
TS 6
(+5)
16.50
18.50
20.50
22.50
24.50
26.50
28.50
30.50
32.50
54.00
56.00
58.00
60.00
62.00
64.00
66.00

APPENDIX D

DATA

This appendix presents the data obtained from the experiment runs. Scatter diagrams of Range and CPA are presented by watch segment and subject type (i.e., VLCC untrained - Vu, VLCC trained - Vt,containership - C). The diagrams are grouped by watch and also by the three between-subject variables of restriction, crossing situation, and traffic density. The basic raw data of range and CPA are numerically listed and various computed means and standard deviations (S.D.) are also given.

The appendix concludes with a presentation, by subject grouping, of maneuvering data including type (left turn - L, right turn - R, speed reduction - S), size of maneuver (maximum course change in degrees), and number of maneuvers/ orders. Attained CPAs are also shown.

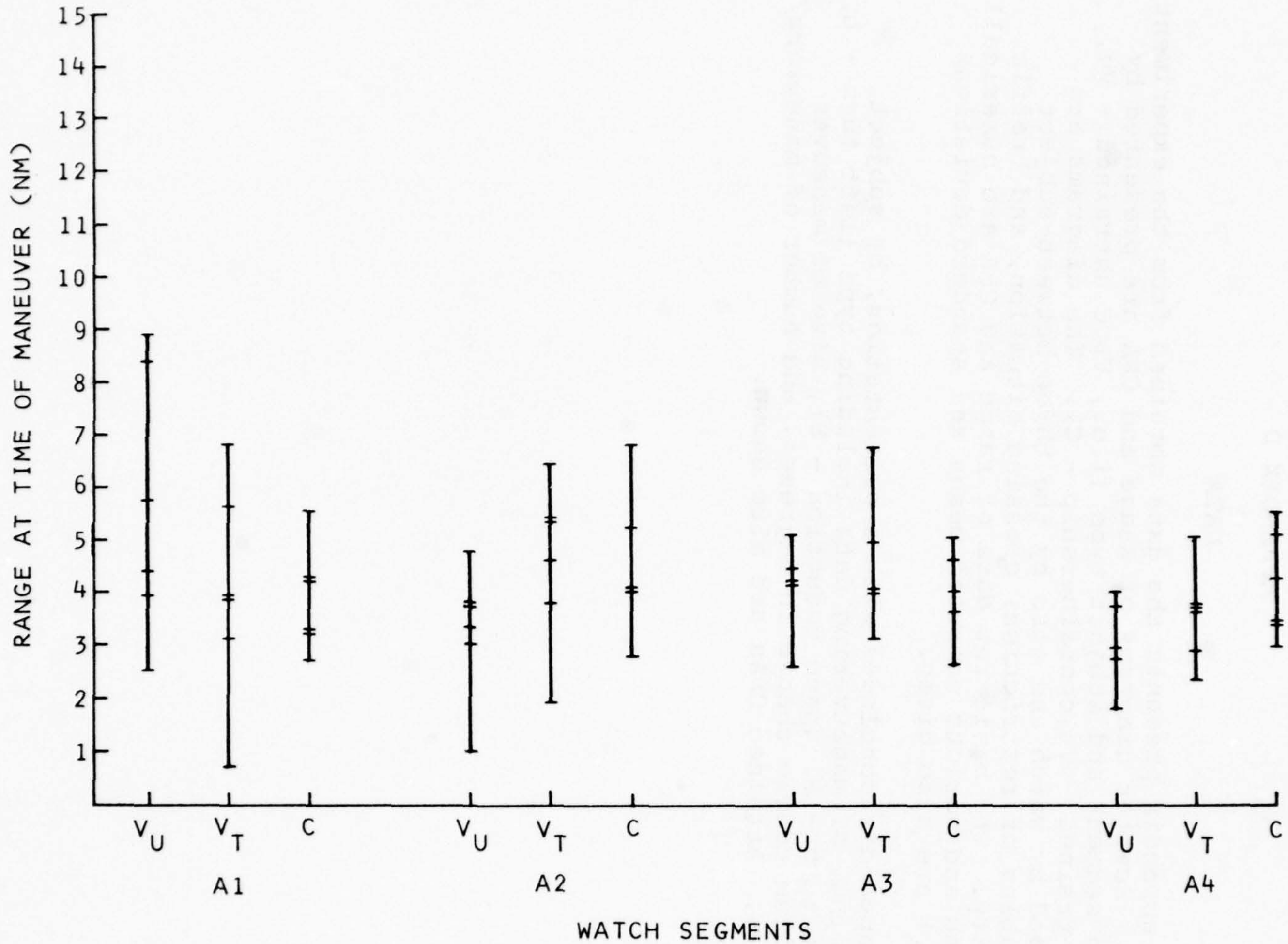


Figure D-1A. A Watch - Range

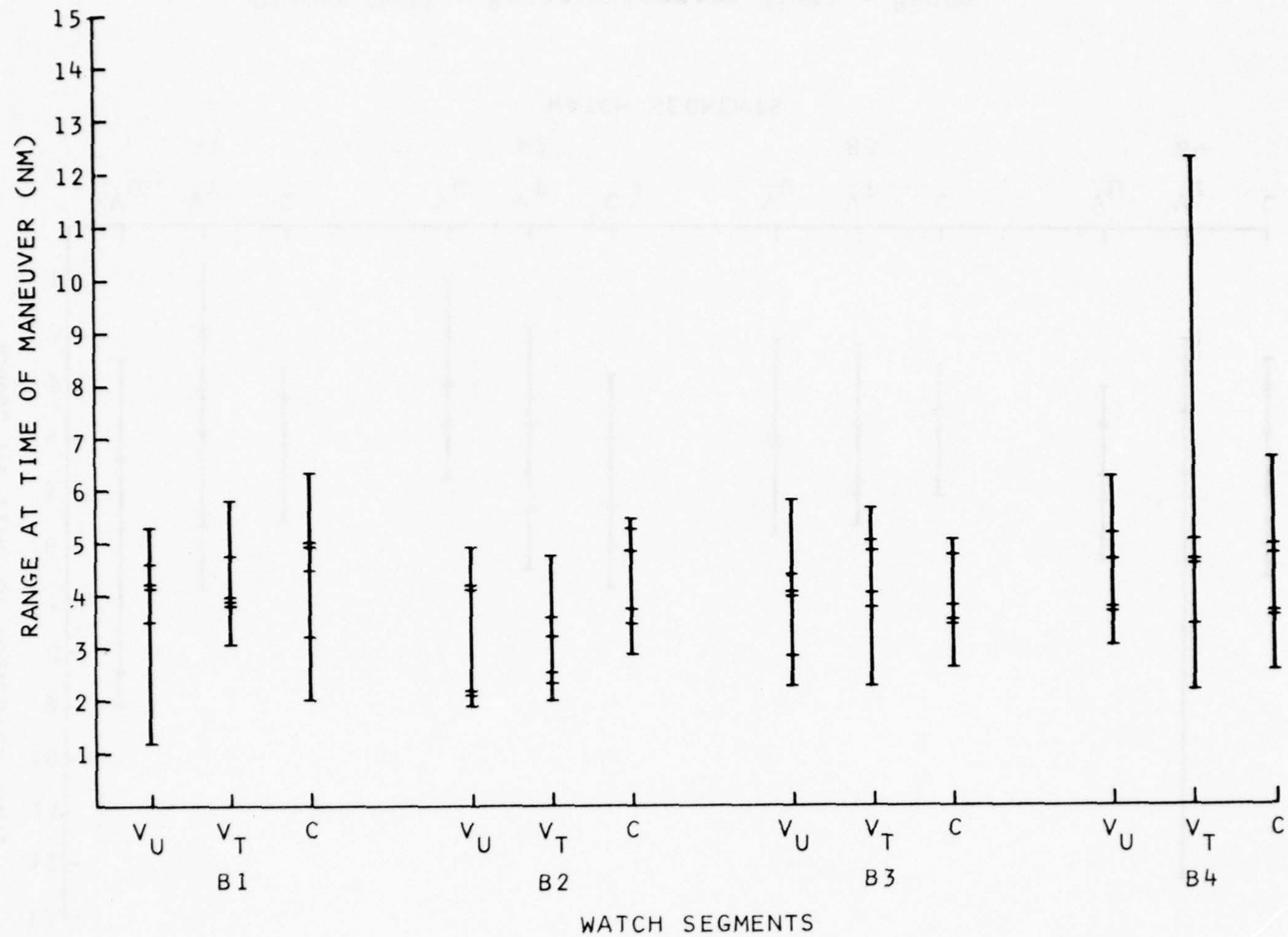


Figure D-1B. B Watch - Range

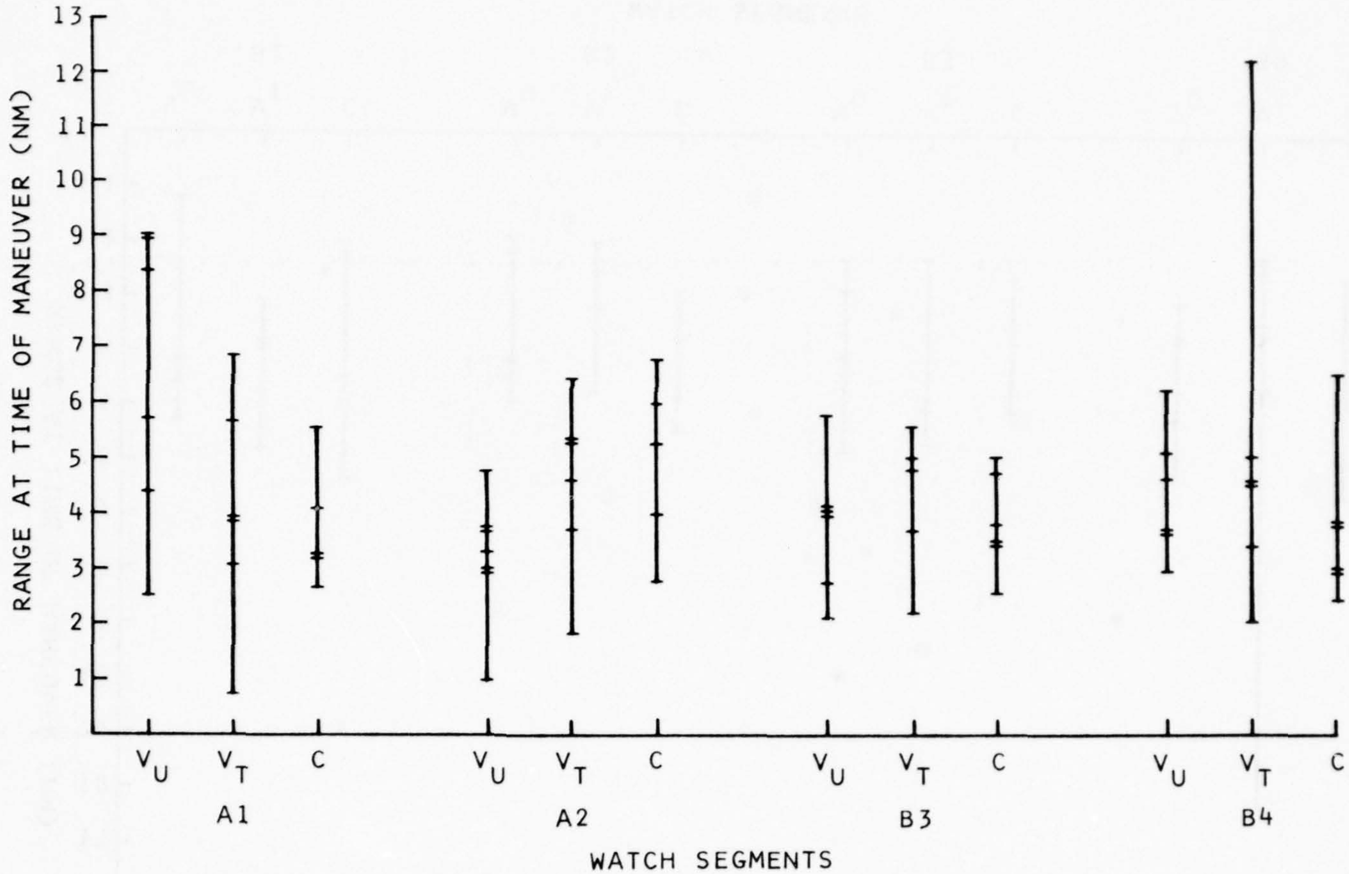


Figure D-2A. Restrictions on Right - Range

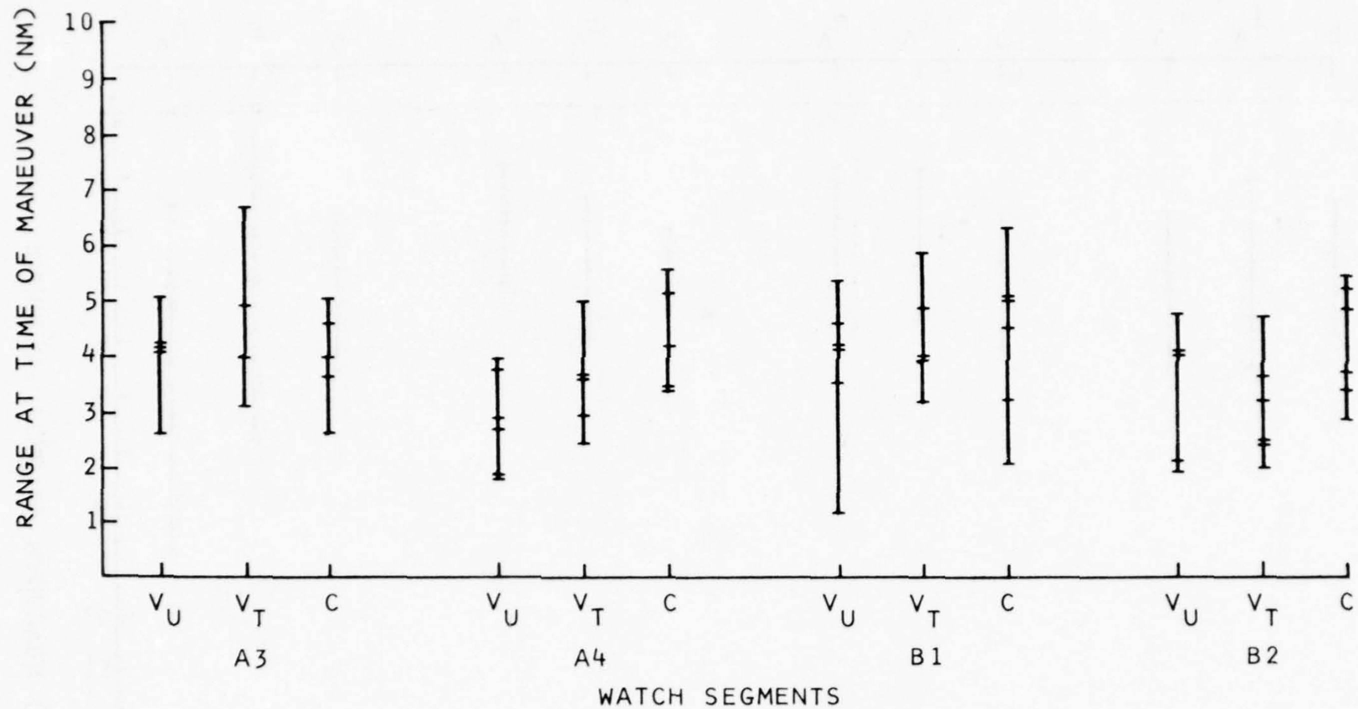


Figure D-2B. No Restrictions on Right - Range

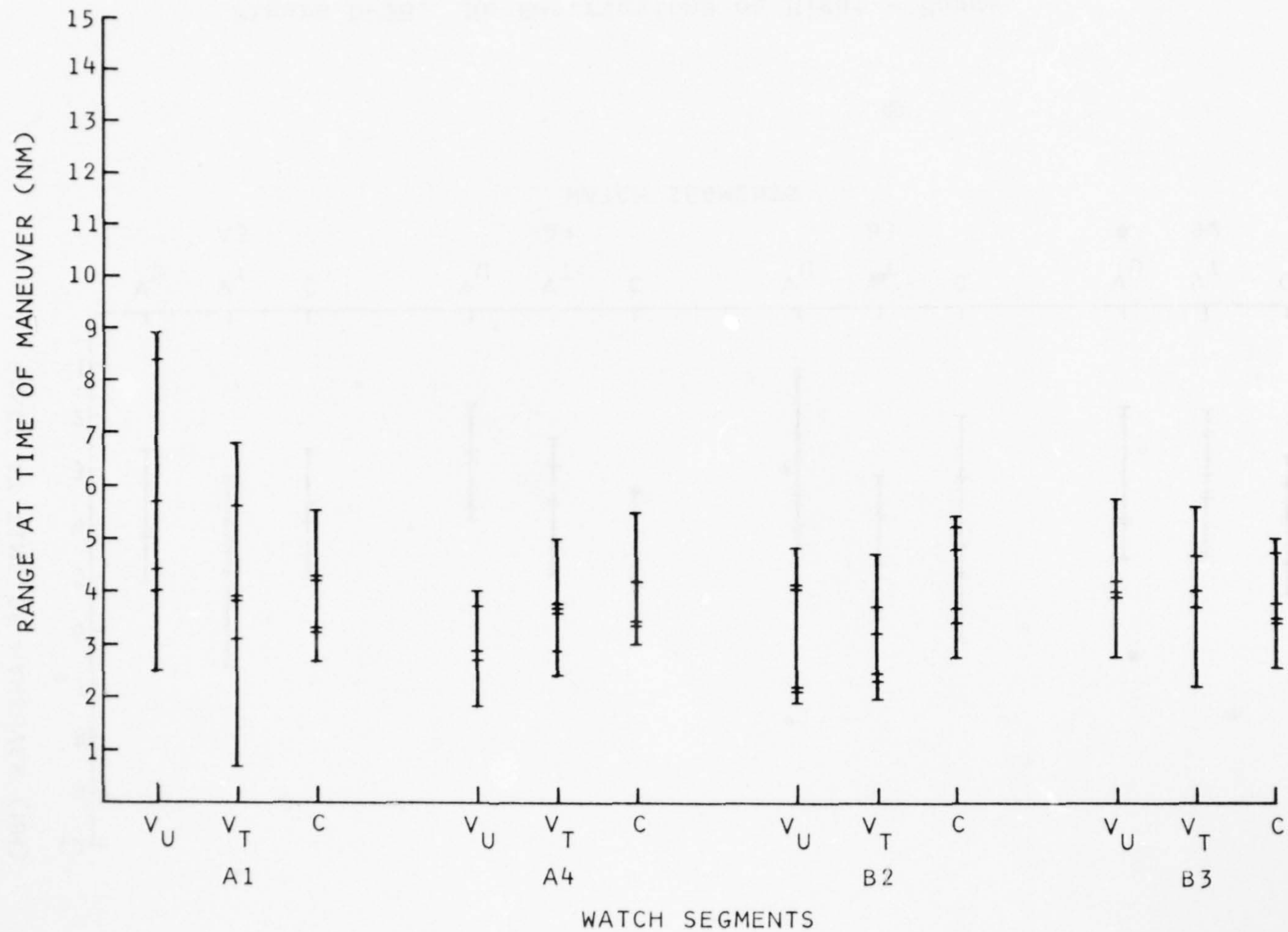


Figure D-3A. Clear-Cut Crossing - Range

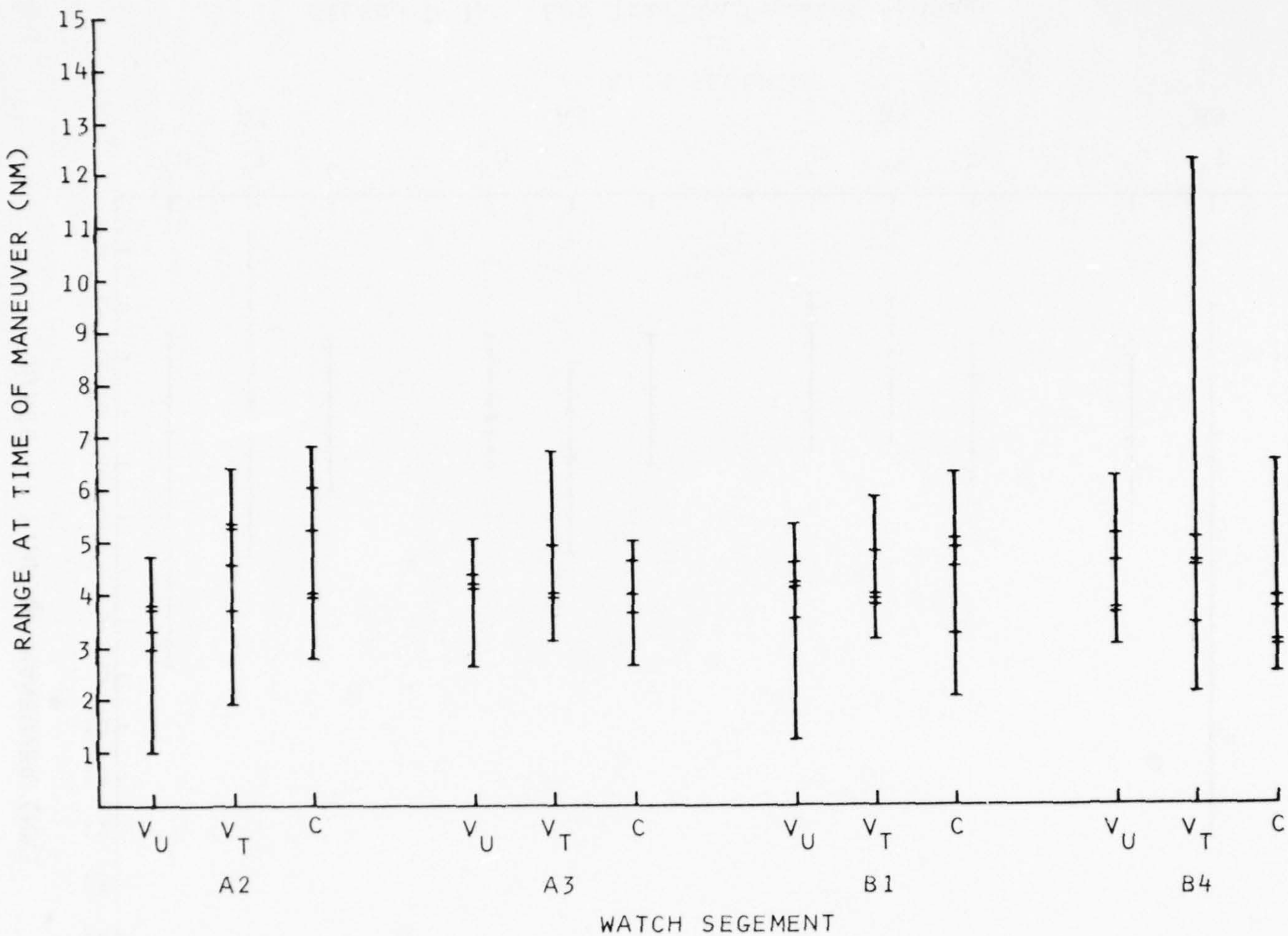


Figure D-3B. Ambiguous Crossing - Range

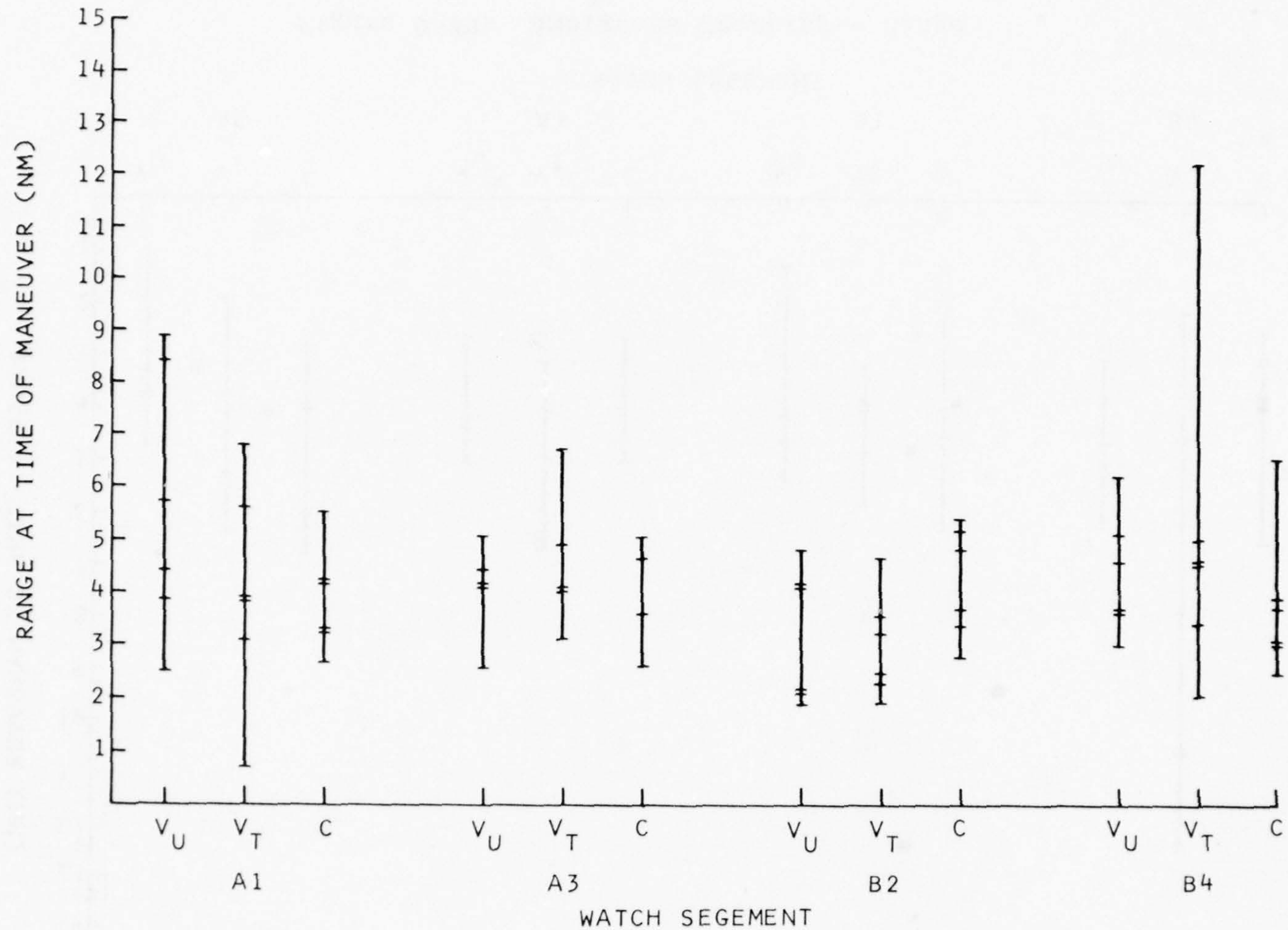


Figure D-4A. Low Traffic Density - Range

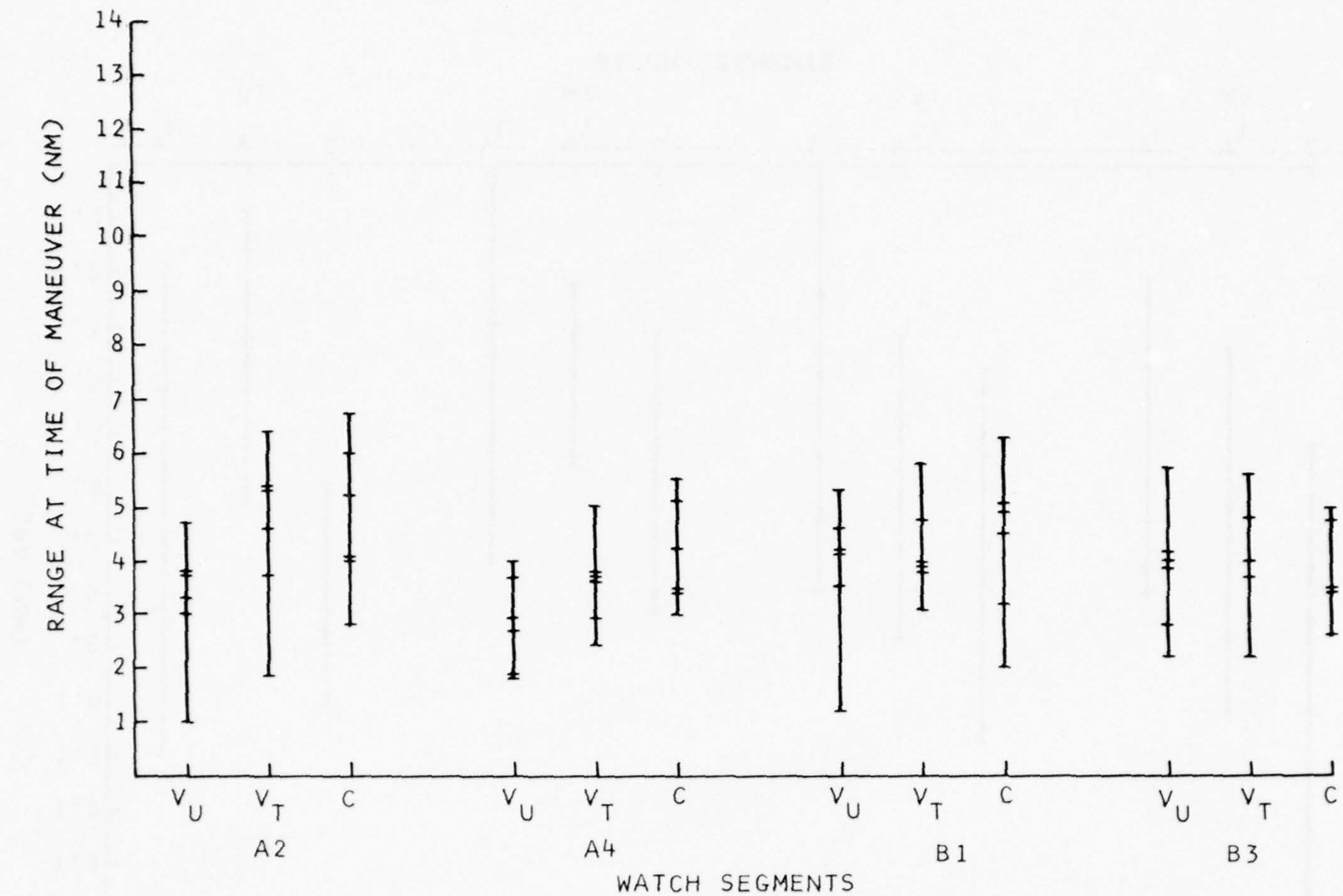


Figure D-4B. High Traffic Density - Range

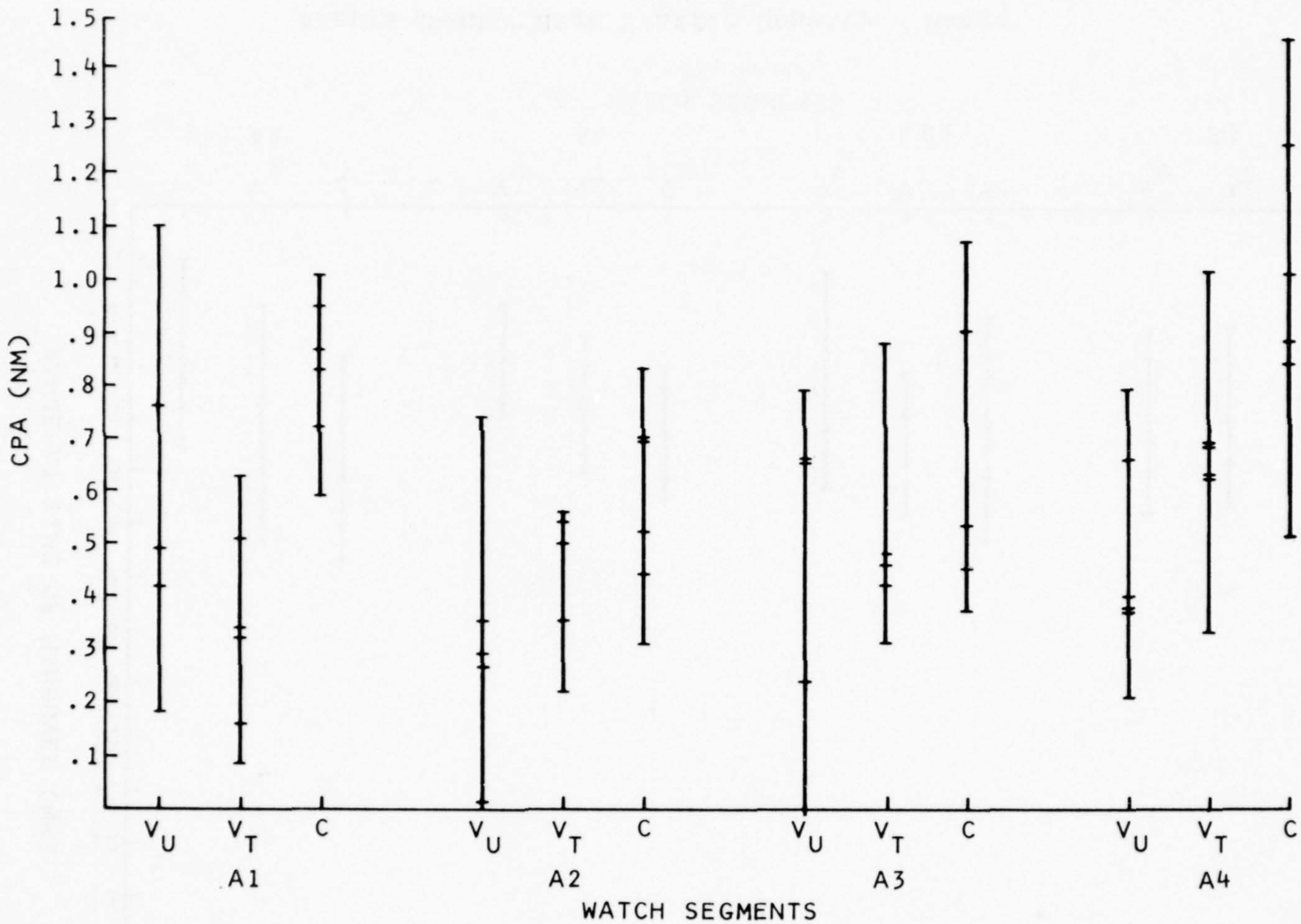


Figure D-5A. A Watch - CPA

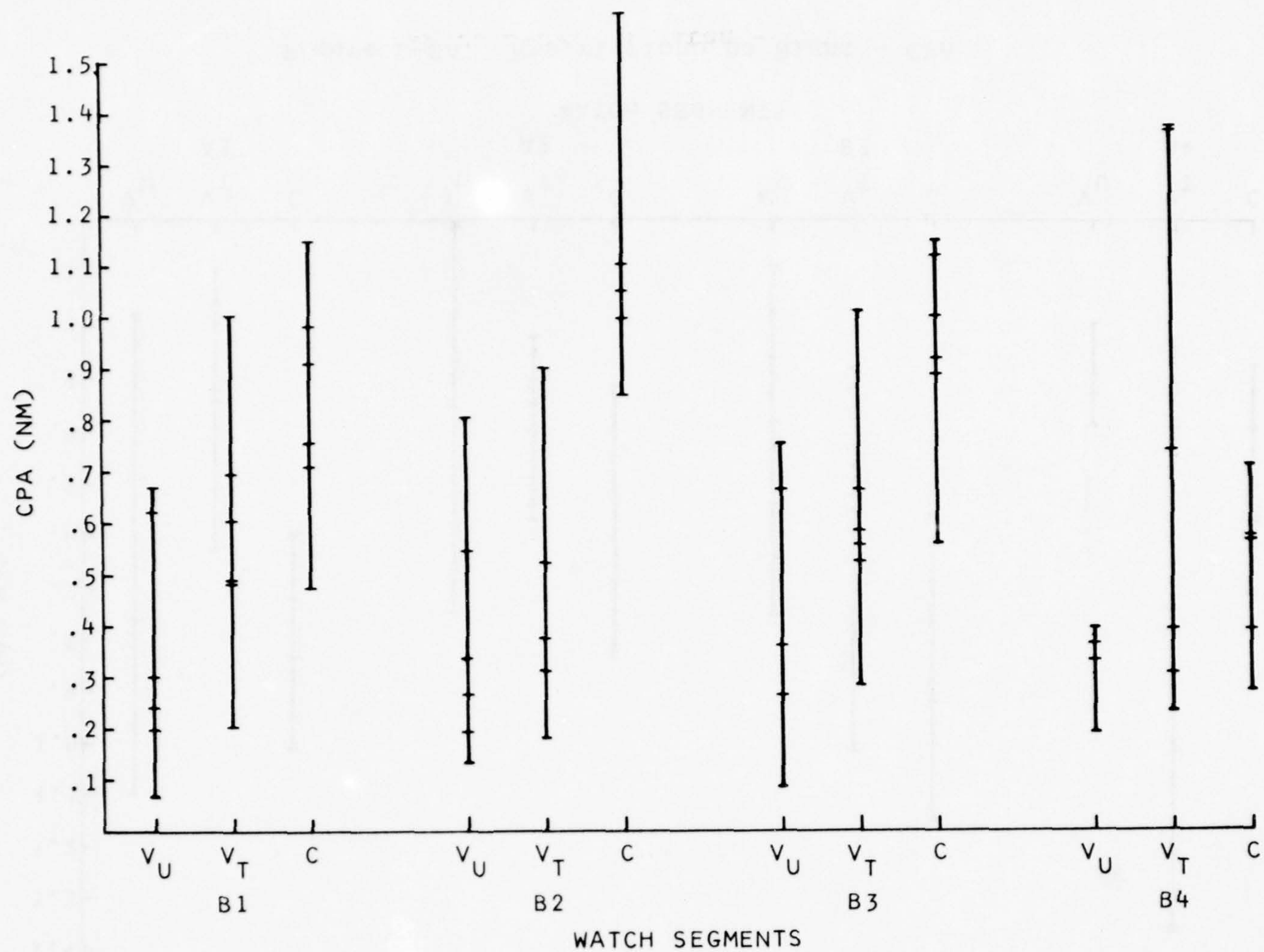


Figure D-5B. B Watch - CPA

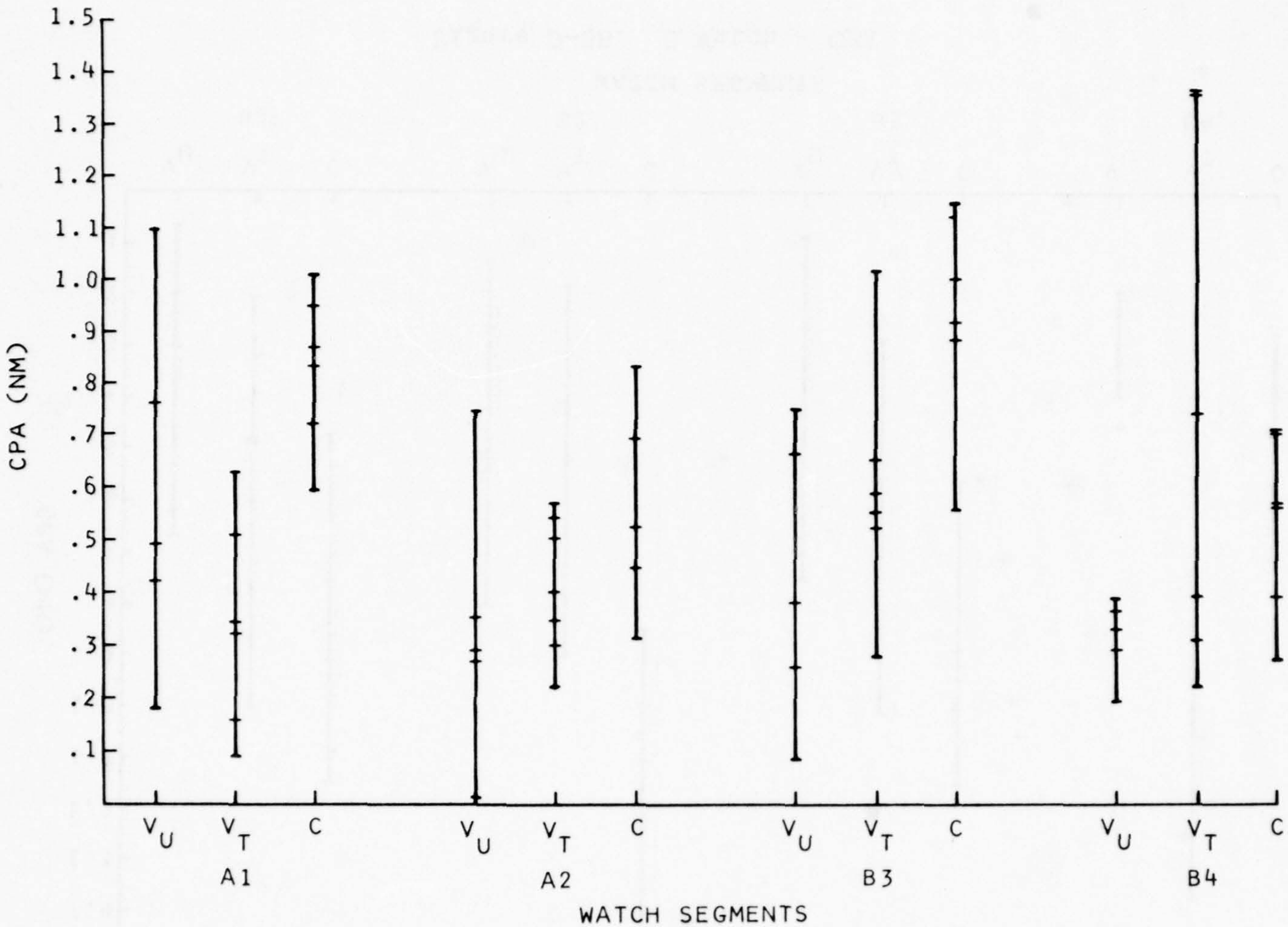


Figure D-6A. Restrictions on Right - CPA

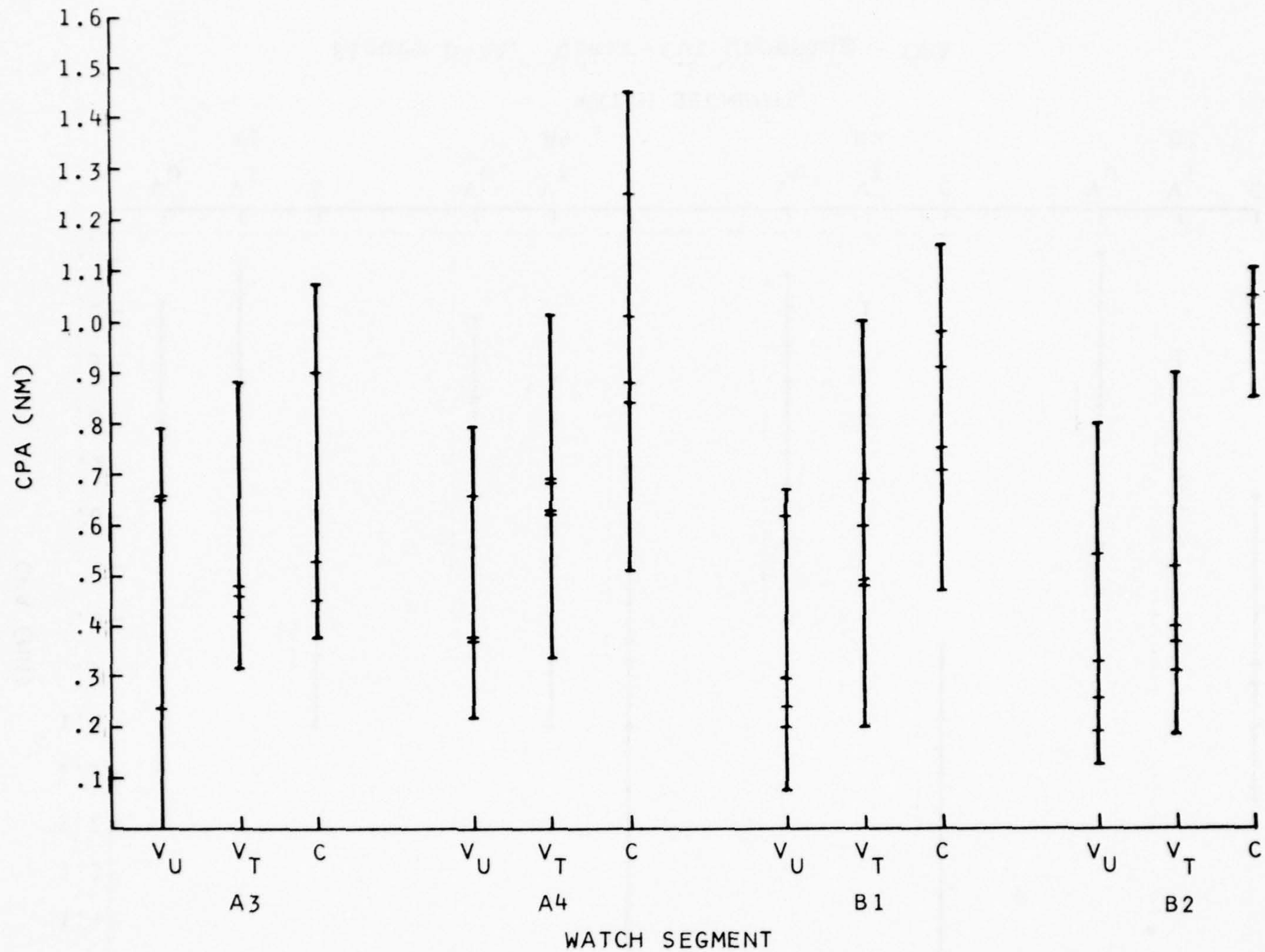


Figure D-6B. No Restrictions on Right - CPA

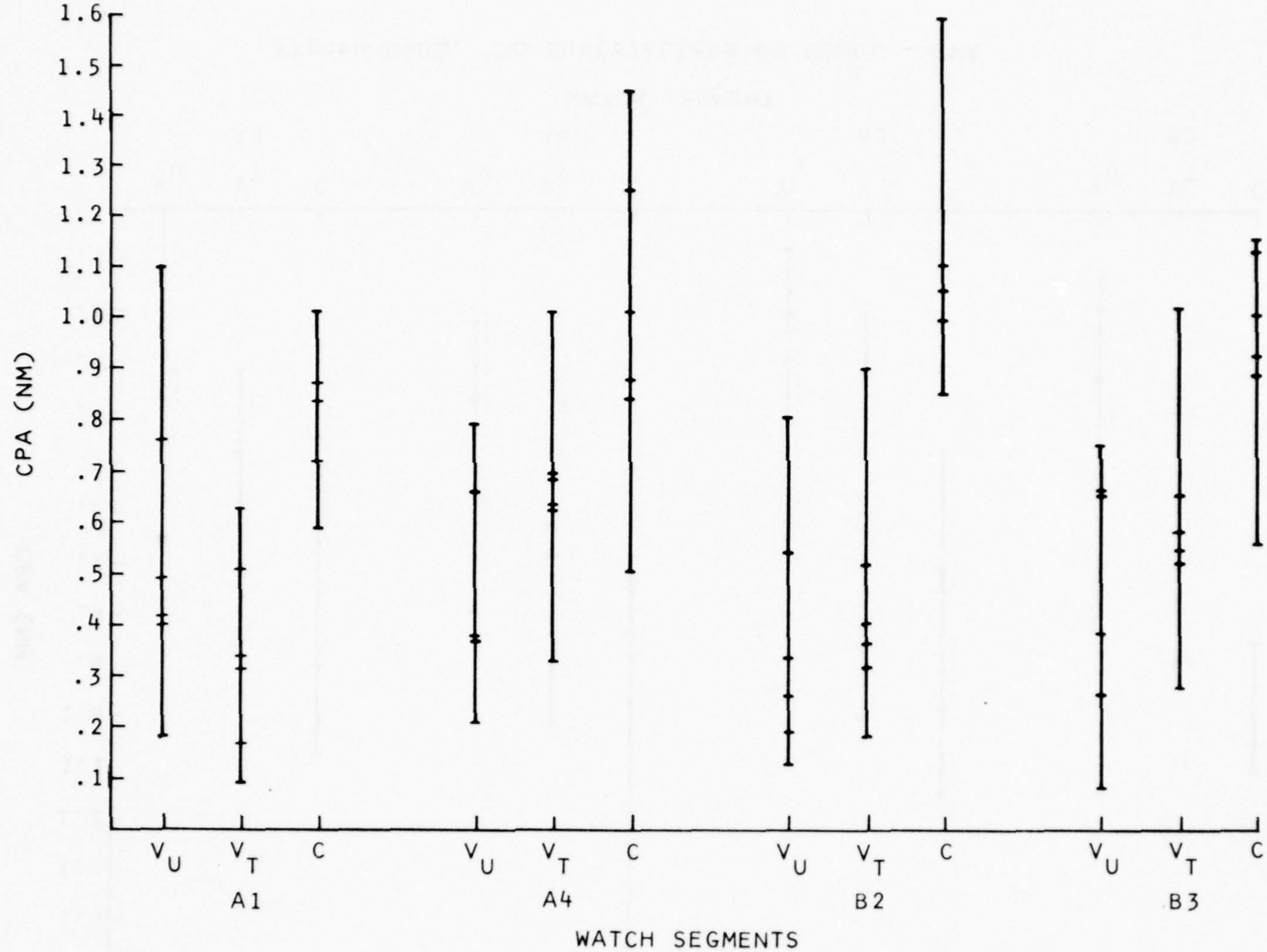


Figure D-7A. Clear-Cut Crossing - CPA

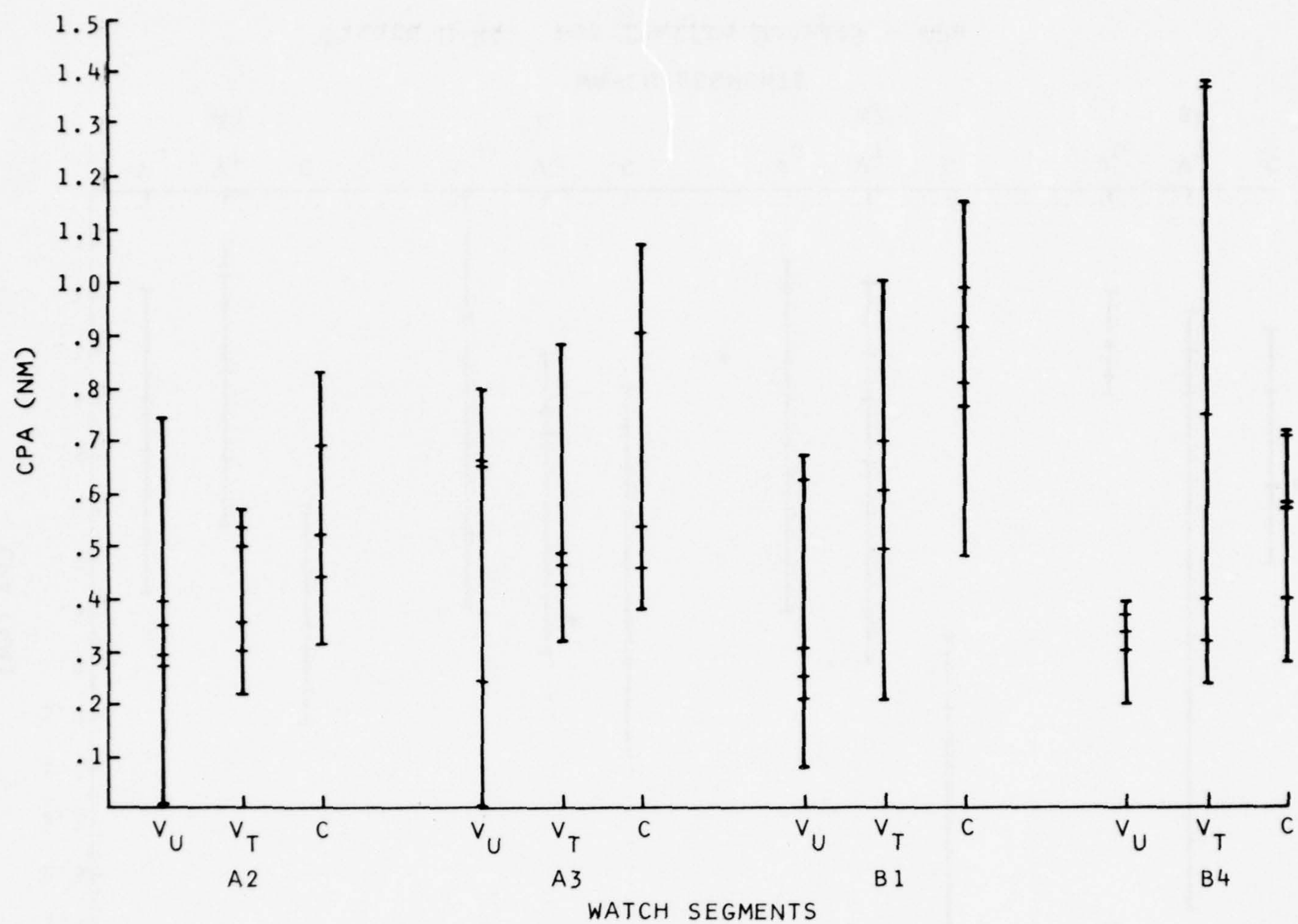


Figure D-7B. Ambiguous Crossing - CPA.

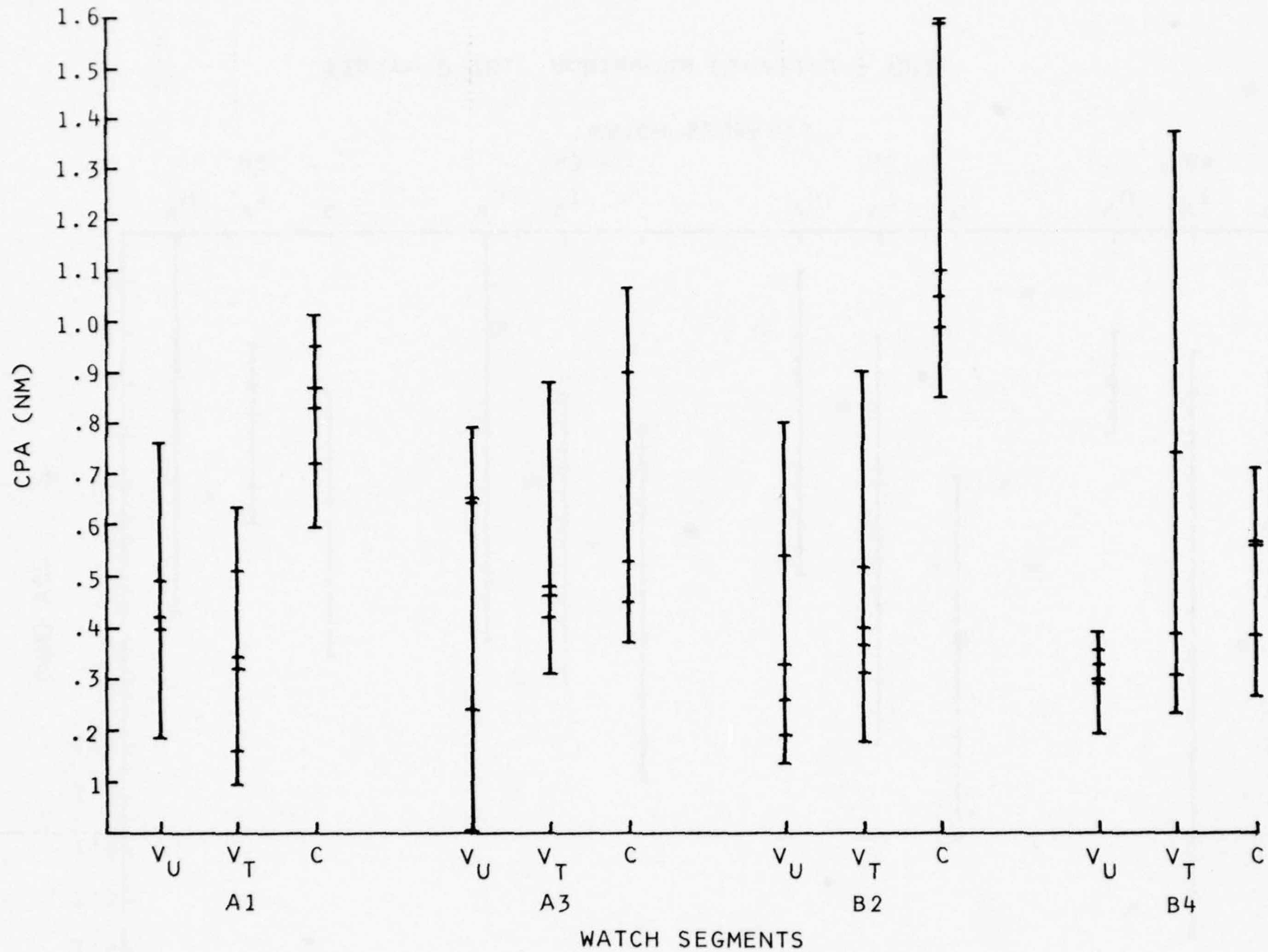


Figure D-8A. Low Traffic Density - CPA

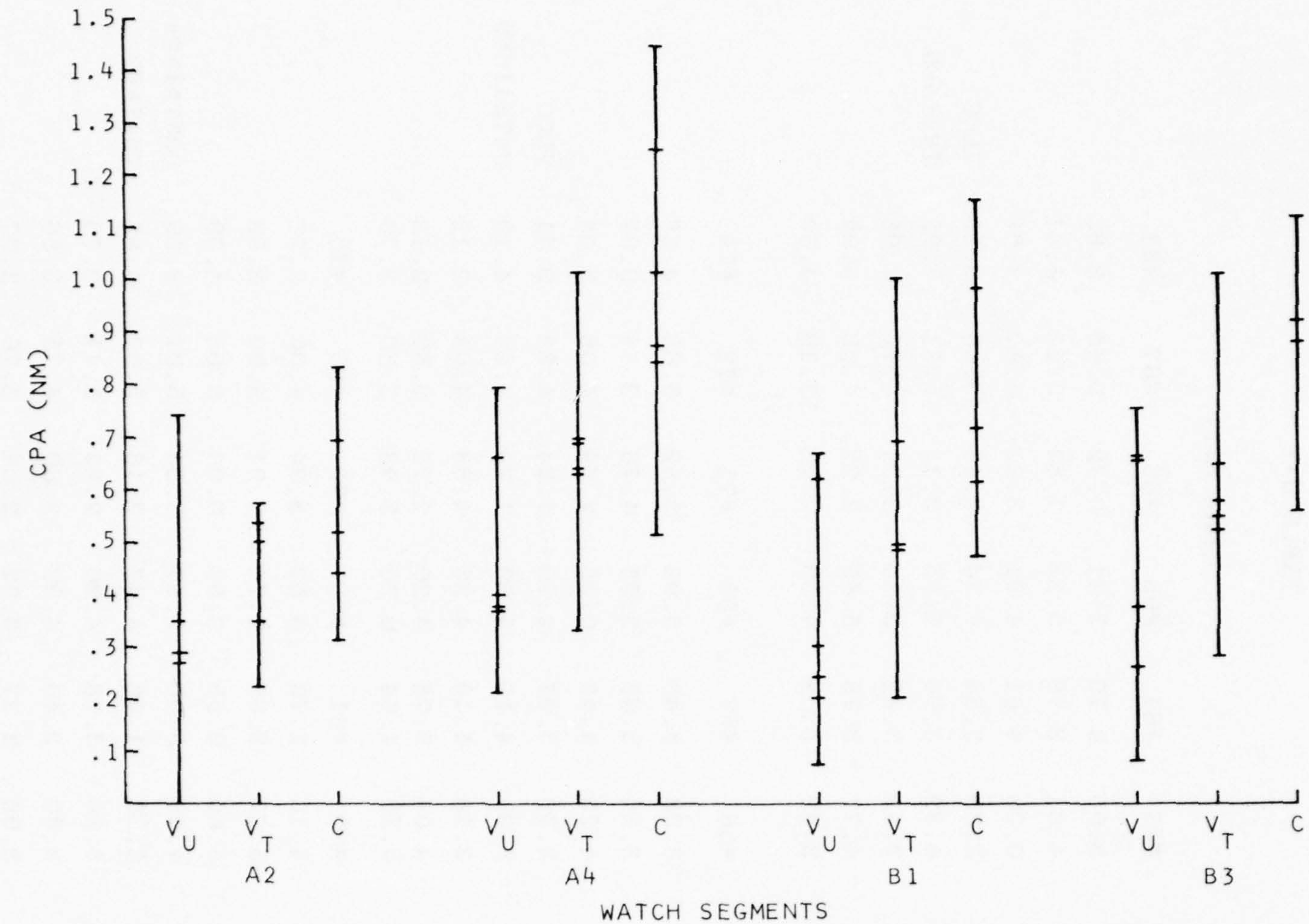


Figure D-8B. High Traffic Density - CPA

TABLE D-1

RANGE (nm)

	#58	#64	#65	#66	#67	#68	
A1V	3.05	6.79	3.91	0.72	5.65	3.85	
A2V	4.61	3.76	5.38	1.84	5.26	6.41	
A3V	0.00	4.01	4.91	3.92	6.67	3.08	
A4V	2.90	3.54	4.94	2.40	3.65	3.53	VLCC
B1V	4.82	3.96	3.83	3.13	5.81	3.92	TRAINED
B2V	2.49	3.62	3.14	2.31	4.73	1.96	
B3V	4.77	3.76	5.62	2.22	4.99	3.92	
B4V	3.42	5.02	4.50	2.10	12.19	4.60	

	#56	#57	#59	#71	#72	#74	
A1V	8.88	8.40	3.96	2.52	5.68	4.38	
A2V	3.30	3.65	2.95	4.76	3.74	0.97	
A3V	4.20	4.42	0.00	2.58	4.06	5.05	
A4V	2.90	3.97	2.70	1.84	1.83	3.71	VLCC
B1V	5.30	4.10	4.60	1.20	3.49	4.19	UNTRAINED
B2V	2.16	4.10	4.80	1.88	4.08	2.12	
B3V	4.04	5.76	4.20	2.78	3.89	2.13	
B4V	5.10	4.64	6.20	2.98	3.60	3.70	

	#60	#61	#62	#63	#69	#70	
A1C	4.10	2.70	5.52	3.24	4.06	3.21	
A2C	5.20	2.80	6.74	3.91	5.99	3.99	
A3C	4.60	2.59	3.59	0.00	5.03	4.09	
A4C	4.20	3.00	5.47	3.36	5.07	3.39	CONTAINER
B1C	6.30	1.98	4.47	3.16	5.02	4.88	TRAINED
B2C	5.20	3.38	4.80	2.82	5.41	3.73	
B3C	3.80	3.40	4.92	2.60	4.75	3.56	
B4C	3.90	2.97	6.52	2.54	3.76	3.07	

TABLE D-1
(continued)

MEAN	SD	
4.13	1.49	TOTAL TRAINED
4.01	1.67	TOTAL VLCC
4.10	1.14	CONTAINER TRAINED
4.16	1.78	VLCC TRAINED
3.86	1.57	VLCC UNTRAINED
4.16	1.75	SIMPLE
3.93	1.24	MULTIPLE
4.25	1.58	AMBIGUOUS
3.85	1.43	CROSSING
4.28	1.76	RESTRICTED
3.80	1.16	UNRESTRICTED

TABLE D-2

CPA(nm)

	#58	#64	#65	#66	#67	#68	
A1V	0.32	0.51	0.34	0.09	0.63	0.16	
A2V	0.50	0.30	0.57	0.22	0.54	0.35	
A3V	0.00	0.46	0.42	0.48	0.88	0.31	
A4V	0.69	0.63	1.01	0.33	0.68	0.63	
B1V	0.49	0.60	0.20	0.49	1.00	0.69	VLCC
B2V	0.40	0.52	0.37	0.31	0.90	0.18	TRAINED
B3V	0.52	0.55	1.01	0.28	0.65	0.58	
B4V	0.23	1.37	0.74	0.31	1.36	0.39	

	#56	#57	#59	#71	#72	#74	
A1V	1.10	0.76	0.49	0.18	0.42	0.40	
A2V	0.35	0.74	0.40	0.27	0.29	0.04	
A3V	0.24	0.65	0.00	0.02	0.65	0.79	
A4V	0.40	0.79	0.37	0.21	0.38	0.66	
B1V	0.24	0.20	0.30	0.07	0.67	0.62	
B2V	0.19	0.54	0.33	0.13	0.80	0.26	VLCC
B3V	0.08	0.66	0.75	0.38	0.66	0.26	UNTRAINED
B4V	0.33	0.39	0.30	0.19	0.36	0.30	

	#60	#61	#62	#63	#69	#70	
A1C	0.95	0.72	0.87	0.83	0.59	1.01	
A2C	0.69	0.44	0.31	0.83	0.70	0.52	
A3C	0.37	0.53	0.45	0.00	1.07	0.90	
A4C	0.51	0.88	0.84	1.45	1.25	1.01	CONTAINER
B1C	0.75	0.47	0.71	1.15	0.91	0.98	TRAINED
B2C	1.10	0.85	0.99	1.60	1.60	1.05	
B3C	1.00	1.12	0.56	0.88	0.92	1.15	
B4C	0.70	0.57	0.27	0.71	0.39	0.56	

TABLE D-2

(continued)

MEAN	SD	
0.68	0.33	TOTAL TRAINED
0.48	0.27	TOTAL VLCC
0.82	0.31	CONTAINER TRAINED
0.54	0.29	VLCC TRAINED
0.42	0.24	VLCC UNTRAINED
0.58	0.36	SIMPLE
0.60	0.30	MULTIPLE
0.53	0.29	AMBIGUOUS
0.66	0.35	CROSSING
0.55	0.30	RESTRICTED
0.63	0.35	UNRESTRICTED

TABLE D-3

	MEAN	SD	
A1V	3.99	2.11	
A2V	4.54	1.59	
A3V	4.52	1.37	
A4V	3.49	0.86	VLCC TRAINED RANGE
B1V	4.24	0.94	BASED ON SCENARIO BY SUBJECT TYPE
B2V	3.04	1.02	
B3V	4.21	1.20	
B4V	5.31	3.53	
A1V	5.64	2.54	
A2V	3.23	1.26	
A3V	4.06	0.91	
A4V	2.82	0.90	VLCC UNTRAINED RANGE
B1V	3.81	1.41	BASED ON SCENARIO BY SUBJECT TYPE
B2V	3.19	1.28	
B3V	3.80	1.26	
B4V	4.37	1.18	
A1C	3.81	1.00	
A2C	4.77	1.47	
A3C	3.98	0.95	
A4C	4.08	1.01	CONTAINER TRAINED RANGE
B1C	4.30	1.52	BASED ON SCENARIO BY SUBJECT TYPE
B2C	4.22	1.06	
B3C	3.84	0.87	
B4C	3.79	1.43	

TABLE D-3

(continued)

	MEAN	SD	
A1V	0.34	0.20	
A2V	0.41	0.14	
A3V	0.51	0.22	
A4V	0.66	0.22	VLCC TRAINED CPA
B1V	0.58	0.26	BASED ON SCENARIO BY SUBJECT TYPE
B2V	0.45	0.25	
B3V	0.60	0.24	
B4V	0.73	0.52	
A1V	0.56	0.32	
A2V	0.35	0.23	
A3V	0.47	0.33	
A4V	0.47	0.21	VLCC UNTRAINED CPA
B1V	0.35	0.24	BASED ON SCENARIO BY SUBJECT TYPE
B2V	0.38	0.25	
B3V	0.46	0.27	
B4V	0.31	0.07	
A1C	0.83	0.15	
A2C	0.58	0.19	
A3C	0.66	0.30	
A4C	0.99	0.33	CONTAINER TRAINED CPA
B1C	0.83	0.24	BASED ON SCENARIO BY SUBJECT TYPE
B2C	1.20	0.32	
B3C	0.94	0.21	
B4C	0.53	0.17	

TABLE D-4

	MEAN	SD	
#58	3.72	0.99	
#64	4.31	1.10	
#65	4.53	0.85	VLCC TRAINED RANGE
#66	2.33	0.93	BASED ON SUBJECT TOTALS
#67	6.12	2.61	
#68	3.91	1.27	
#56	4.49	2.07	
#57	4.88	1.56	
#59	4.20	1.18	VLCC UNTRAINED RANGE
#71	2.57	1.06	BASED ON SUBJECT TOTALS
#72	3.80	1.05	
#74	3.28	1.39	
#60	4.66	0.86	
#61	2.85	0.46	
#62	5.25	1.04	CONTAINER TRAINED RANGE
#63	3.09	0.48	BASED ON SUBJECT TOTALS
#69	4.89	0.71	
#70	3.74	0.58	
#58	0.45	0.15	
#64	0.62	0.32	
#65	0.58	0.31	VLCC TRAINED CPA
#66	0.31	0.13	BASED ON SUBJECT TOTALS
#67	0.83	0.27	
#68	0.41	0.20	

TABLE D-4

(continued)

	MEAN	SD	
#56	0.37	0.31	
#57	0.59	0.21	
#59	0.42	0.16	VLCC UNTRAINED CPA
#71	0.18	0.11	BASED ON SUBJECT TOTALS
#72	0.53	0.19	
#74	0.42	0.25	
#60	0.76	0.25	
#61	0.70	0.24	
#62	0.63	0.27	CONTAINER TRAINED CPA
#63	1.06	0.34	BASED ON SUBJECT TOTALS
#69	0.93	0.38	
#70	0.90	0.23	

TABLE D-5

	MEAN	SD	
A1	4.48	2.05	
A2	4.18	1.53	
A3	4.19	1.04	
A4	3.47	1.02	RANGE - BASED ON SCENARIO TOTALS
B1	4.12	1.26	
B2	3.48	1.19	
B3	3.95	1.07	
B4	4.49	2.26	

	MEAN	SD	
A1	0.58	0.30	
A2	0.45	0.21	
A3	0.55	0.28	
A4	0.71	0.33	CPA - BASED ON SCENARIO TOTALS
B1	0.59	0.31	
B2	0.67	0.46	
B3	0.67	0.30	
B4	0.53	0.35	

MEAN	SD	
4.04	1.51	RANGE TOTALS
0.59	0.33	CPA TOTALS

TABLE D-6A.

MANEUVERING DATA - VLCC UNTRAINED

A WATCH

		A_1	A_2	A_3	A_4
	MANEUVERING DATA	LD R CC	HD R A	LD NR A	HD NR CC
#56	MAGNITUDE	17°		27°	5°
	TYPE	L	S	R	R
	NUMBER	3		5	2
	CPA	1.1	.35	.24	.40
#57	MAGNITUDE	28°	39°	39°	50°
	TYPE	R	L	R	R
	NUMBER	1	2	1	1
	CPA	.76	.74	.65	.79
#59	MAGNITUDE	4°	7°	—	20°
	TYPE	L	L	—	R
	NUMBER	1	1	—	4
	CPA	.49	.40	—	.37
#71	MAGNITUDE		17°		43°
	TYPE	S	R	S	R
	NUMBER	3	2		1
	CPA	.18	.27	.02	.21
#72	MAGNITUDE		57°	60°	64°
	TYPE	S	R	R	R
	NUMBER		2	2	1
	CPA	.42	.29	.65	.38
#74	MAGNITUDE	17°	28°	72°	40°
	TYPE	S-L	R	R	R
	NUMBER	1	1	3	1
	CPA	.40	.04	.79	.66

Traffic Density	- High	= HD
	- Low	= LD
Restrictions	- Without	= NR
	- With	= R
Crossing	- Clear - Cut	= CC
	- Ambiguous	= A

TABLE D-6B

MANEUVERING DATA - VLCC UNTRAINED

B WATCH

		B_1	B_2	B_3	B_4
	MANEUVERING DATA	HD NR A	LD NR CC	HD R CC	LD R A
#56	MAGNITUDE	15^o	45^o		15^o
	TYPE	R	R	S-L	R
	NUMBER	5	3	1	5
	CPA	.24	.19	.08	.33
#57	MAGNITUDE	10^o	35^o	36^o	15^o
	TYPE	R	R	R	R
	NUMBER	2	2	2	1
	CPA	.20	.54	.66	.39
#59	MAGNITUDE	35^o	129^o	87^o	15^o
	TYPE	R	R	R	R
	NUMBER	7	8	3	3
	CPA	.30	.33	.75	.30
#71	MAGNITUDE	17^o	69^o	66^o	16^o
	TYPE	R	R	R	R
	NUMBER	1	1	1	2
	CPA	.07	.13	.38	.19
#72	MAGNITUDE	51^o	61^o	55^o	20^o
	TYPE	R	R	R	R
	NUMBER	1	1	1	1
	CPA	.67	.80	.66	.36
#74	MAGNITUDE	33^o	84^o	57^o	18^o
	TYPE	R	R	R	R
	NUMBER	1	2	1	1
	CPA	.62	.26	.26	.30

Traffic Density - High = HD
- Low = LD

Restrictions - Without = NR
- With = R

Crossing - Clear - Cut = CC
- Ambiguous = A

TABLE D-7A.

MANEUVERING DATA - VLCC TRAINED

A WATCH

	MANEUVERING DATA	A_1 LD R CC	A_2 HD R A	A_3 LD NR A	A_4 HD NR CC
#58	MAGNITUDE	77^o	75^o	——	76^o
	TYPE	R	R	——	R
	NUMBER	1	1	——	1
	CPA	.32	.50	——	.69
#64	MAGNITUDE	7^o	52^o	43^o	47^o
	TYPE	S-L	R	R	R
	NUMBER	4	2	1	1
	CPA	.51	.30	.46	.63
#65	MAGNITUDE	123^o	13^o	15^o	117^o
	TYPE	R	L	R	R
	NUMBER	1	1	1	1
	CPA	.34	.57	.42	1.01
#66	MAGNITUDE	19^o	2^o	31^o	49^o
	TYPE	L	L	R	R
	NUMBER	1	1	1	1
	CPA	.09	.22	.48	.33
#67	MAGNITUDE	13^o	18^o	25^o	66^o
	TYPE	L	R	R	R
	NUMBER	2	1	2	2
	CPA	.63	.54	.88	.68
#68	MAGNITUDE	53^o	21^o	25^o	32^o
	TYPE	R	R	R	R
	NUMBER	2	2	1	1
	CPA	.16	.35	.31	.63

Traffic Density - High = HD
- Low = LD

Restrictions - Without = NR
- With = R

Crossing - Clear - Cut = CC
- Ambiguous = A

TABLE D-7B.

MANEUVERING DATA - VLCC TRAINED

B WATCH

	MANEUVERING DATA	B_1 HD NR A	B_2 LD NR CC	B_3 HD R CC	B_4 LD R A
#58	MAGNITUDE	21^{o}	88^{o}	22^{o}	16^{o}
	TYPE	R	R	R	R
	NUMBER	2	2	1	1
	CPA	.49	.40	.52	.23
#64	MAGNITUDE	46^{o}	61^{o}	63^{o}	72^{o}
	TYPE	R	R	R	L
	NUMBER	1	1	1	1
	CPA	.60	.52	.55	1.37
#65	MAGNITUDE	7^{o}	111^{o}	62^{o}	88^{o}
	TYPE	R	R	R	R
	NUMBER	1	1	2	4
	CPA	.20	.37	1.01	.74
#66	MAGNITUDE	46^{o}	69^{o}	70^{o}	59^{o}
	TYPE	R	R	R	R
	NUMBER	1	1	1	1
	CPA	.49	.31	.28	.31
#67	MAGNITUDE	41^{o}	80^{o}	61^{o}	21^{o}
	TYPE	R	R	R	L
	NUMBER	2	3	3	1
	CPA	1.00	.90	.65	1.36
#68	MAGNITUDE	42^{o}	113^{o}	41^{o}	16^{o}
	TYPE	R	R	R	R
	NUMBER	1	1	1	1
	CPA	.69	.18	.58	.39

Traffic Density - High = HD
- Low = LD
Restrictions - Without = NR
- With = R
Crossing - Clear - Cut = CC
- Ambiguous = A

TABLE D-8A.

MANEUVERING DATA - CONTAINERSHIP TRAINED

A WATCH

		A_1	A_2	A_3	A_4
	MANEUVERING DATA	LD R CC	HD R A	LD NR A	HD NR CC
#60	MAGNITUDE	23^{o}	16^{o}	10^{o}	20^{o}
	TYPE	R	R	R	R
	NUMBER	2	2	1	2
	CPA	.95	.69	.37	.51
#61	MAGNITUDE	38^{o}	18^{o}	15^{o}	25^{o}
	TYPE	R	R	R	L
	NUMBER	1	2	2	1
	CPA	.72	.44	.53	.85
#62	MAGNITUDE	23^{o}	5^{o}	20^{o}	25^{o}
	TYPE	R	R	R	R
	NUMBER	2	1	2	2
	CPA	.87	.31	.45	.84
#63	MAGNITUDE	39^{o}	20^{o}	—	40^{o}
	TYPE	R	R	—	R
	NUMBER	2	1	—	1
	CPA	.83	.83	—	1.45
#69	MAGNITUDE		13^{o}	30^{o}	35^{o}
	TYPE	S	R	R	R
	NUMBER		2	3	3
	CPA	.59	.70	1.07	1.25
#70	MAGNITUDE	49^{o}	13^{o}	20^{o}	45^{o}
	TYPE	R	R	R	R
	NUMBER	1	1	1	1
	CPA	1.01	.52	.90	1.01

Traffic Density - High = HD
- Low = LD

Restrictions - Without = NR
- With = R

Crossing - Clear -Cut= CC
- Ambiguous = A

TABLE D-8B

MANEUVERING DATA - CONTAINERSHIP TRAINED

B WATCH

	MANEUVERING DATA	B_1 HD NR A	B_2 LD NR CC	B_3 HD R CC	B_4 LD R A
#60	MAGNITUDE	10^o	25^o	30^o	17^o
	TYPE	R	R	R	R
	NUMBER	1	2	1	2
	CPA	.75	1.10	1.00	.70
#61	MAGNITUDE	10^o	60^o	40^o	17^o
	TYPE	R	R	R	R
	NUMBER	1	3	2	2
	CPA	.47	.85	1.12	.57
#62	MAGNITUDE	10^o	10^o	10^o	2^o
	TYPE	R	R	R	R
	NUMBER	1	1	1	1
	CPA	.71	1.00	.56	.27
#63	MAGNITUDE	31^o	52^o	37^o	28^o
	TYPE	R	R	R	R
	NUMBER	1	2	1	1
	CPA	1.15	1.57	.88	.71
#69	MAGNITUDE	15^o	41^o	31^o	7^o
	TYPE	R	R	R	R
	NUMBER	1	3	2	1
	CPA	.91	1.60	.92	.39
#70	MAGNITUDE	15^o	30^o	38^o	17^o
	TYPE	R	R	R	R
	NUMBER	1	1	1	1
	CPA	.98	1.05	1.15	.56

Traffic Density - High = HD
- Low = LD

Restrictions - Without = NR
- With = R

Crossing - Clear - Cut = CC
- Ambiguous = A

APPENDIX E

DESCRIPTION OF CAORF

CAORF is a sophisticated ship-maneuvering simulator operated by the U.S. Maritime Administration for controlled research into man-ship-environment problems. Controlled experiments, which might require several vessels, cannot be performed readily in the real world and would certainly be ruled out for testing situations that involve potential danger. Such experiments can be performed safely and easily at CAORF. A simplified cutaway of the simulator building is shown in Figure E-1 and the relationships among the major subsystems are illustrated in Figure E-2.

All actions called for by the watch officer on the bridge are fed through a central computer that alters the visual scene and all bridge displays and repeaters in accordance with the calculated dynamic response of ownship and the environmental situation being simulated. CAORF has the capability of simulating any ship, port, or area in the world. The major subsystems are:

- <u>Wheelhouse</u> which contains all the equipment and controls needed by the test subject watch officer to maneuver ownship through a scenario, and includes propulsion and steering controls, navigational equipment, and communication gear

- <u>Central Data Processor</u> which computes the motion of ownship in accordance with its known characteristics, models the behavior of all other traffic ships, and drives the appropriate bridge indicators

- <u>Image Generator</u> which constructs the computer-generated visual image of the surrounding environment and traffic ships that is projected onto a cylindrical screen for visual realism

- <u>Radar Signal Generator</u> which synthesizes video signals to stimulate the bridge radars and collision avoidance system for the display of traffic ships and surrounding environment

- <u>Control Station</u> from which the experiment can be monitored and (if desired) traffic ships and environment can be controlled

- <u>Human Factors Monitoring Station</u> from which unobtrusive observation and video recording of test subject behavior may be carried out by experimental psychologists

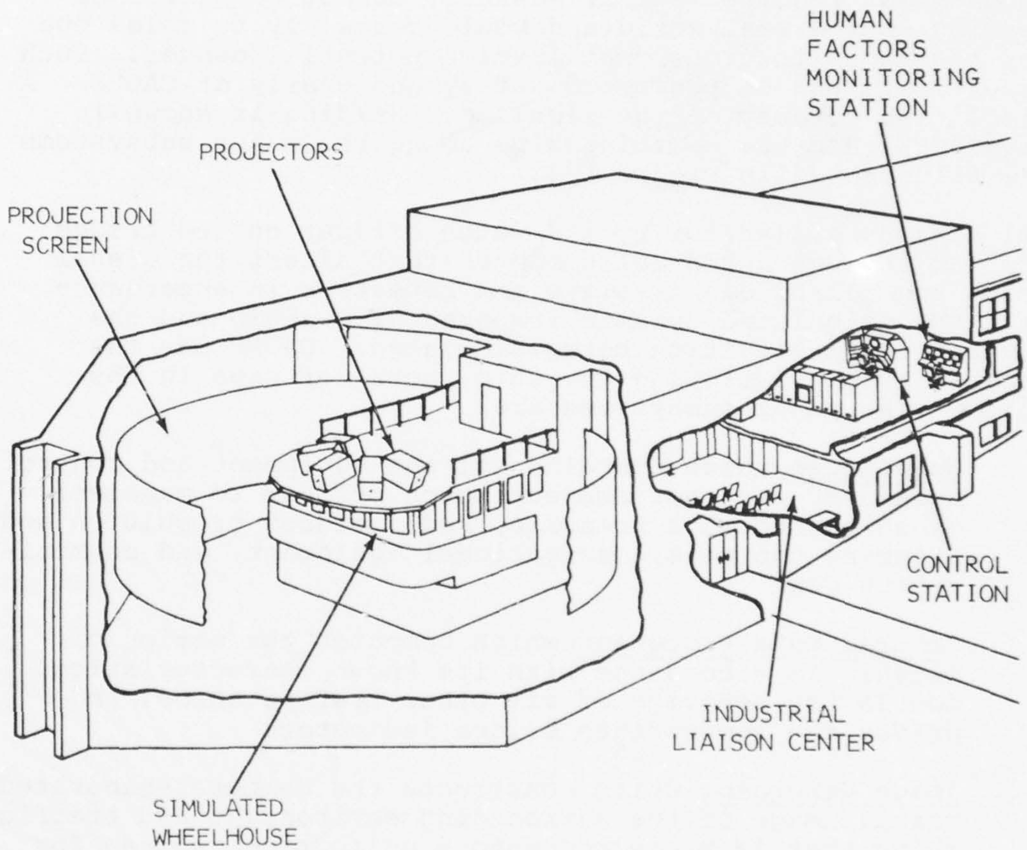


Figure E-1. Cutaway - CAORF Simulator Building

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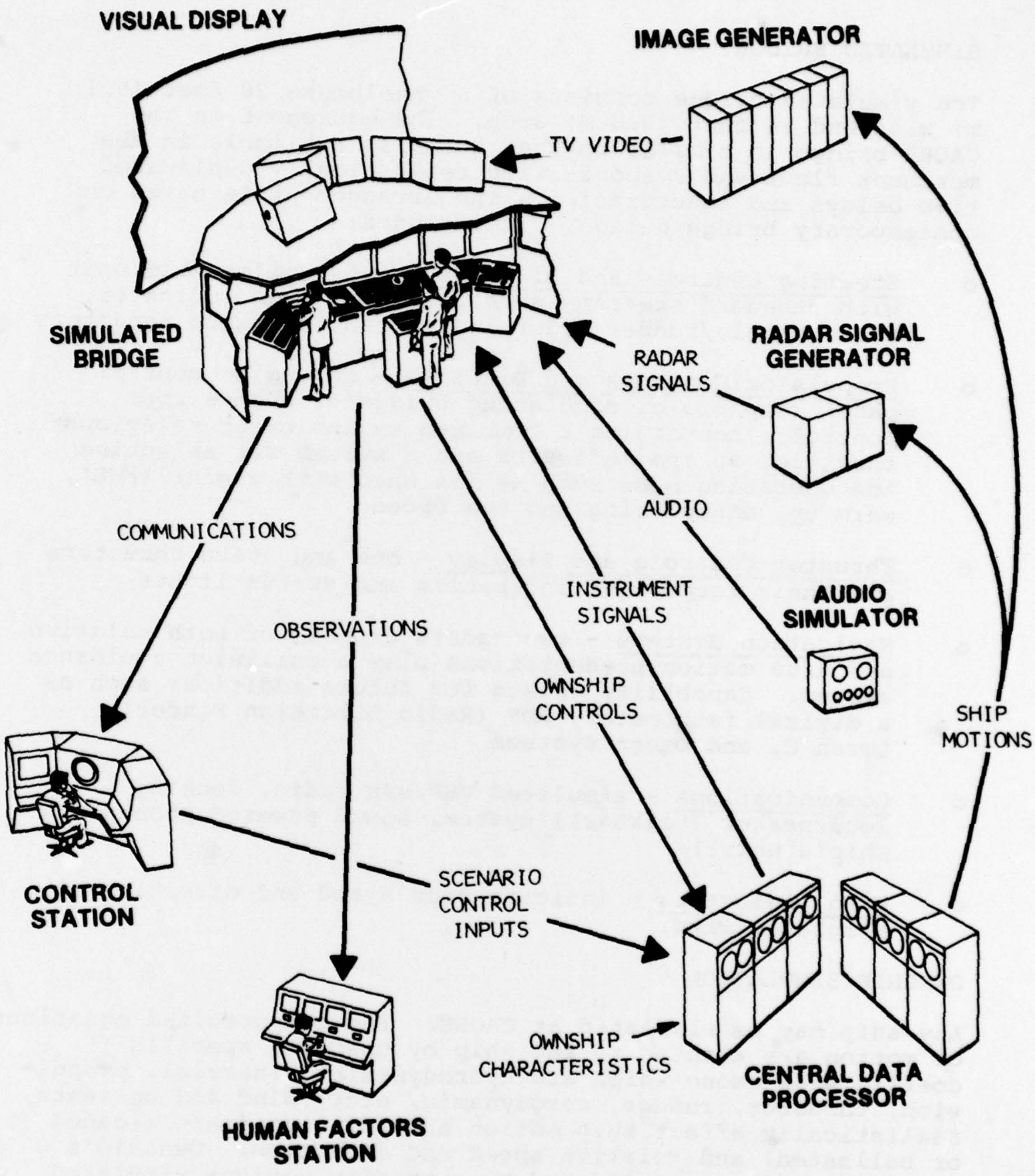

Figure E-2. CAORF Simulator Subsystems

SIMULATED BRIDGE

The simulated bridge consists of a wheelhouse 20 feet (6.1 m) wide and 14 feet (4.3 m) deep. The equipment on the CAORF bridge is similar to that normally available in the merchant fleet and responds with realistically duplicated time delays and inaccuracies. The arrangement is based on contemporary bridge design. It includes:

- Steering Controls and Displays - a gyropilot helm unit with standard steering modes, rate of turn indicator, rudder angle/rudder order indicators, and gyro repeaters
- Propulsion Controls and Displays - an engine control panel (capable of simulating bridge or engine room control), containing a combined engine order telegraph/ throttle, an rpm indicator and a switch for selecting the operating mode such as finished with engine (FWE), warm up, maneuvering and sea speed
- Thruster Controls and Display - bow and stern thrusters and their respective indicators and status lights
- Navigation Systems - two radars capable of both relative and true motion presentations plus a collision avoidance system. Capability exists for future additions such as a digital fathometer, RDF (Radio Direction Finder), Loran C, and Omega systems
- Communications - simulated VHF/SSB radio, docking loudspeaker (talkback) system, sound powered phones and ship's whistle
- Wind Indicators - indicate true speed and direction of simulated wind.

OWNSHIP SIMULATION

Any ship may be simulated at CAORF. The computerized equations of motion are adapted to the ship by changing specific coefficients among which are hydrodynamics, inertial, propulsion, thruster, rudder, aerodynamic, etc. Wind and currents realistically affect ship motion according to draft (loaded or ballasted) and relative speed and direction. Ownship's computer model was validated by comparing various simulated maneuvers (e.g., zig-zag, turning circle, and spiral tests, crash stops and acceleration) with actual sea trial data.

IMAGE GENERATION

The visual scene is duplicated on CAORF to a degree of realism sufficient for valid similation. The scene (Figure E-3) includes all the man-made structures and natural components of the surrounding scene that mariners familiar with the geographical area deem necessary as cues for navigation. Thus, bridges, buoys, lighthouses, tall buildings, mountains, glaciers, piers, coastlines, and islands would be depicted in the scene. In addition, the closest traffic ships and the forebody of ownship appear. All elements in the scene, except ownship's forebody, appear to move in response to ownship's and other ship's maneuvers. The sky is depicted without clouds and the water without waves.

For enhanced realism the scene is projected in full color. The perspective is set for the actual bridge height above waterline for the simulated ship. Shadowing can be varied according to the position of the sun at different times of day.

Environmental conditions also affect the scene. The lighting can be varied continuously from full sun to moonless night. At night, lights can be seen on traffic vessels, buoys, piers, and other points ashore. Visibility in day or night can be reduced to simulate any degree of fog or haze.

RADAR SIGNAL GENERATION

The Radar Signal Generator produces real-time video signals for driving the two radar PPIs. The items displayed are synchronized with the visual scene and include navigation aids, ships, shoreline and other topographical features with appropriate target shadowing, clutter, range attenuation, and receiver noise. The radar gaming area which covers an area of 150 by 200 miles, extends beyond the visual gaming area, which is 50 by 100 miles. Within the radar gaming area, as many as 40 moving traffic ships can be displayed. The radar signal generator also drives the collision avoidance system, which can be slaved to either of the master PPIs.

CONTROL STATION

The control station (Figure E-4) is the central location from which the simulator experiment is controlled and monitored. An experiment can be initiated anywhere within the visual gaming area with any ship traffic configuration. The control station enables the researchers to interface with the watch-standing crew on the bridge, to simulate malfunctions, and

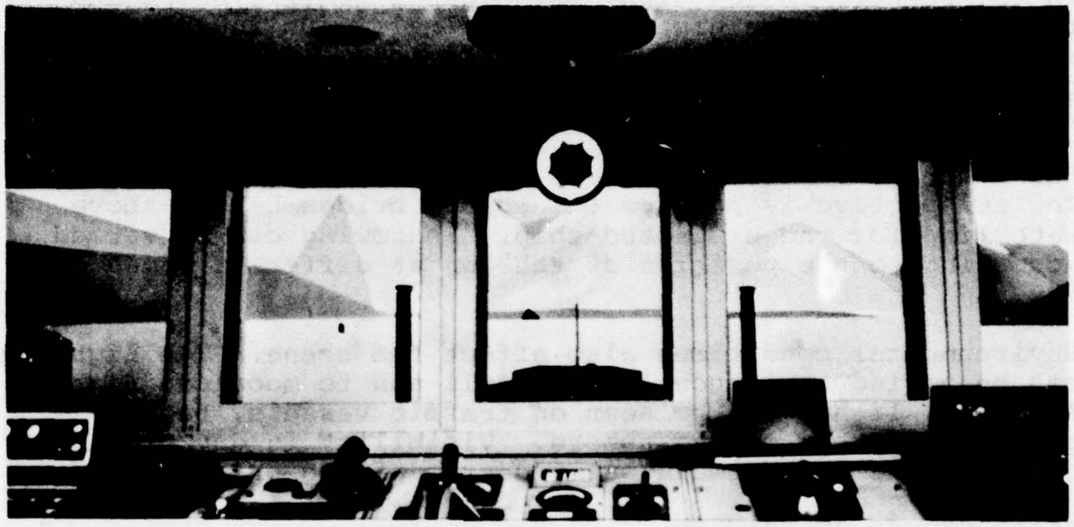

Figure E-3. CAORF Visual Scene - Valdez, Alaska

Figure E-4. CAORF Simulator Control Station

to control the operating mode of the simulator. The Control Station is also capable of controlling motions of traffic ships and tugs in the gaming area and simulating telephone, intercom, radio (VHF, SSB) and whistle contact with the CAORF bridge crew.

HUMAN FACTORS MONITORING STATION

The Human Factors Monitoring Station (Figure E-5) is designed to allow collection of data on crew behavior. Monitoring data is provided by five closed-circuit TV cameras and four microphones strategically located throughout the wheelhouse to record all activities, comments and commands.

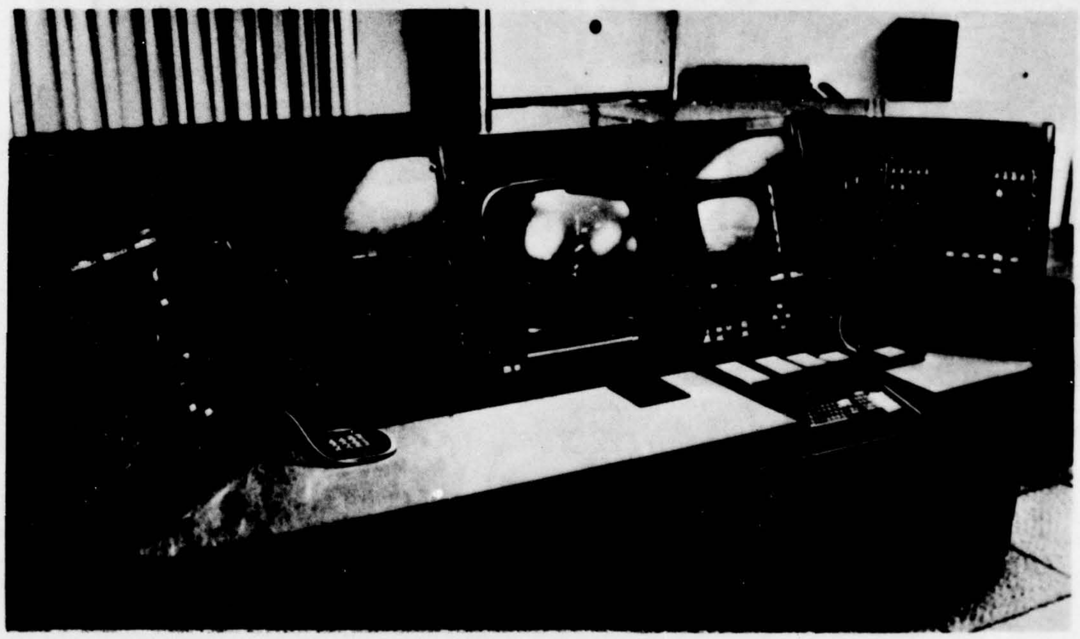

Figure E-5. Human Factors Monitoring Station

APPENDIX F

TEST SUBJECT INDOCTRINATION AND WATCH ORDER INSTRUCTIONS

None of the 18 subjects involved with the Rules of the Road Training Investigation had been fully aware of the activities at the facility other than a vague reference to "research." To bring all subjects up to an even understanding and capability with the simulator, a standard indoctrination/familiarization was accomplished with all subjects, independent of the Rules of the Road training program.

Preliminary indoctrination was accomplished by means of a CAORF orientation writeup, a brochure, a descriptive movie and a discussion with the experiment manager; all immediately upon arrival at the facility. Once the subject was familiar with the aims and background of CAORF and what would be expected of him during his stay, a more detailed equipment-oriented familiarization was begun. Although the test subjects used in this experiment were experienced VLCC and containership officers, they were not familiar with the CAORF bridge and its specific equipment, the handling characteristics of CAORF ownship, the properties of the visual scene, or the specific test procedures that would be used.

A brief period (approximately 2 hours) of familiarization training was given to each test subject before he stood the four-hour experimental watches. He was shown how to operate the primary (Raytheon) radar on the bridge, how to use the phones and radio communication system, all instrumentation was pointed out to him and an explanation of the limitations of the peloruses was given. Two special familiarization sessions were also given on the CAORF bridge:

- Visual familiarization training

- Maneuvering familiarization training

In the visual familiarization, the test subject was given command of an appropriate ownship when it was already underway at 15 knots heading 0° true. Three traffic ships sailed into view and also appeared on the radar (figure F-1). These ships remained clear of ownship and the test subject maintained course and speed with no need to avoid the traffic. The purpose of this run was to permit the test subject to take notice of the appearance of traffic visually and on

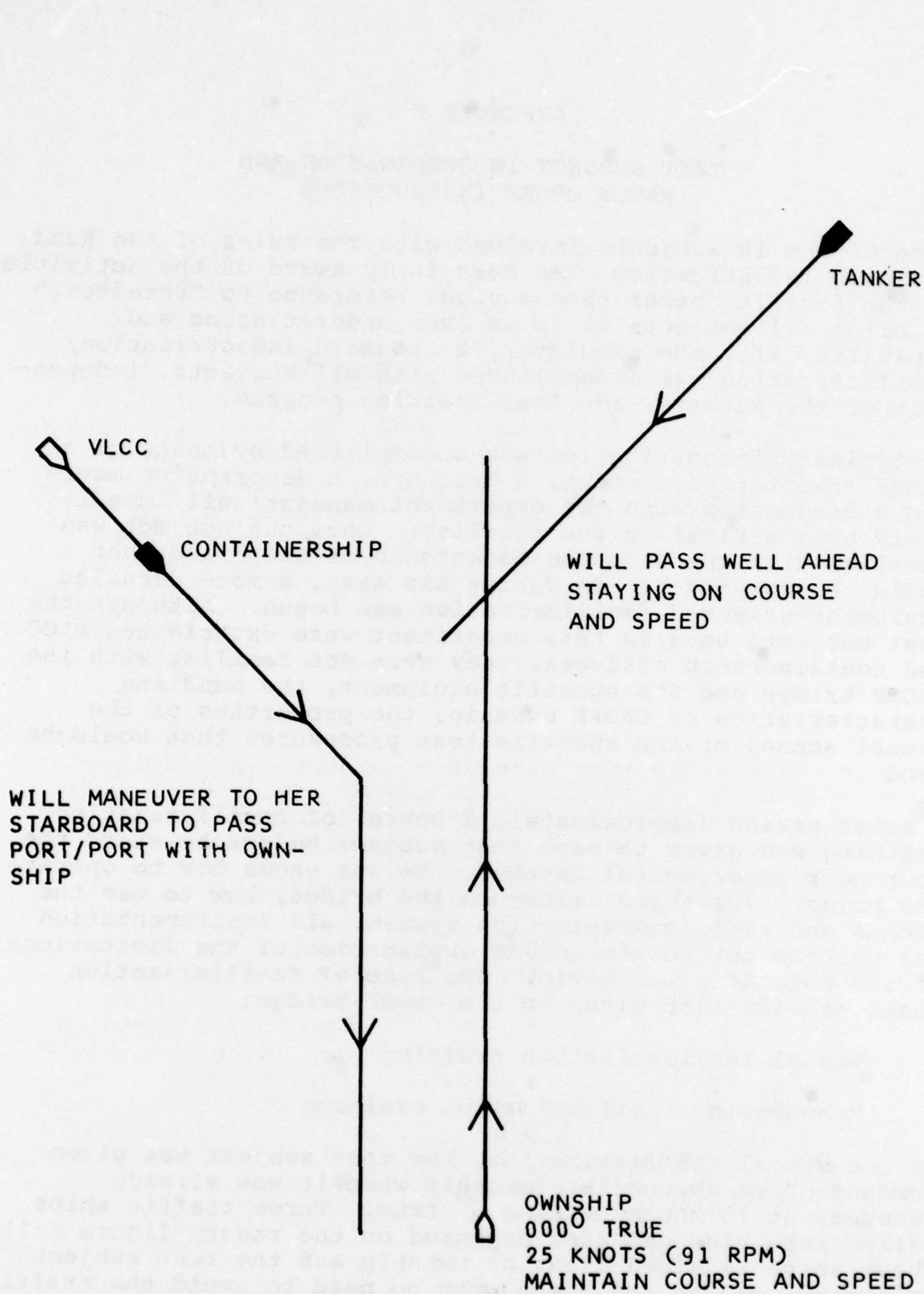

Figure F-1. Visual Familiarization Diagram

radar, and particularly to note how other vessels look at various ranges and at various aspects as they approach ownship.

The resolution of the CAORF visual scene is such that it is difficult to determine the aspect of a traffic ship at ranges beyond approximately three miles. In the real world, a watch officer would be able to use his binoculars to resolve this situation, but this is not possible on the CAORF simulator. In order to provide the desired information, a TV monitor has been installed on the bridge of ownship to simulate the view normally provided through the use of binoculars.

The watch officer can request a "binoculars" view of any ship in the visual scene by calling the bow lookout on the sound-powered phone and giving the relative bearing and range to the traffic ship. Behind the scenes, at the Control Station, a ship model is set at the proper aspect relative to the line of sight of a TV camera. This aspect is based on a current measurement, taken from the situation display by the Control Station operator. The TV monitor is then "turned on" for 15 seconds and a close-up picture of the model ship appears on the TV monitor with the correct aspect and the apparent size of a large vessel, viewed through binoculars at approximately 5 miles. The watch officer is required to view the TV monitor from the sound-powered phone position, a distance of about 8 feet.

For training in the handling characteristics of ownship, a maneuver training course is set up for the subject on CAORF, as shown in figure F-2. Ownship is required to perform the zig-zag maneuvers around the four anchored ships at an engine RPM corresponding to the sea speed of his ship. A speed of 15 knots is indicated in figure F-2, representative of the VLCC training. The watch officer is responsible for giving the required commands to an experienced helmsman present on the bridge and he is told to note the dynamic characteristics of ownship as well as how the speed falls off during the maneuvers. During the familiarization runs each subject, one at a time, was on the bridge with the helmsman and a CAORF staff experimenter who was available for answering questions.

Prior to the start of each watch segment, the test subject was given written watch orders appropriate to his class of ship, by a CAORF staff experiment. Figure F-3 and Figure F-4 are examples of the first and second segment watch orders, which contain environmental and navigational information as well as general instructions. When radar targets were present

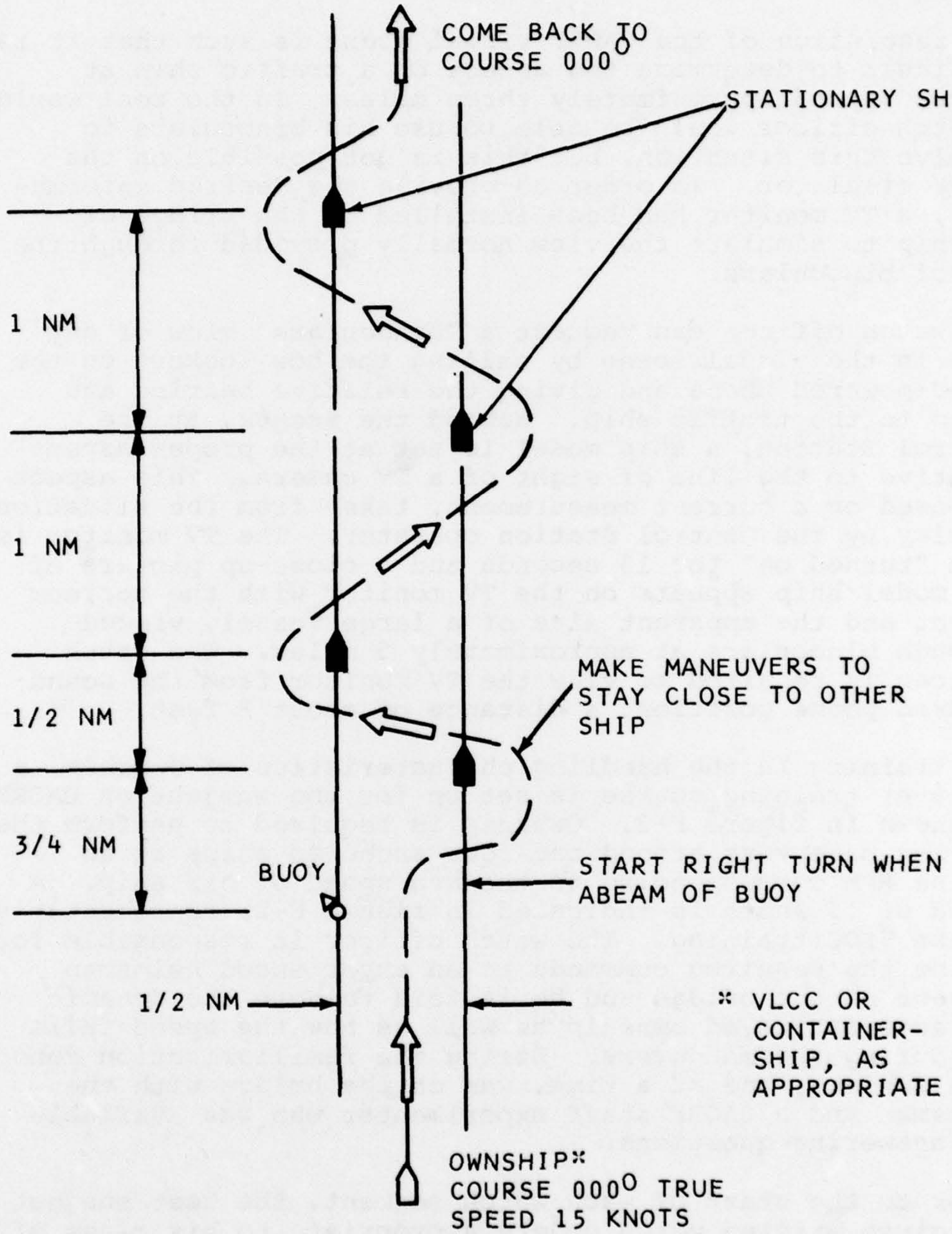

Figure F-2. Maneuver Familiarization Diagram

You are about to assume the 0800 to 1200 bridge watch aboard the VLCC SS CAORF. The ship is in transit, enroute from Port Arthur to Rotterdam. Your present position is southeast of Galveston. The 0800 Loran fix located ownship at 28° 24.8' North latitude and 93° 04.2' West longitude. The local environmental conditions are as follows:

Visibility	unlimited
Wind	light airs
Current	none
Sea state	calm, no swell

Maintain a course of 142° True in the gyro-steering mode and a sea speed of 15 knots using engine control from the bridge Do not alter course and/or speed except to maneuver for traffic. If a maneuver is required maintain what you consider to be a safe passing distance to ship(s) under the given circumstances.

The SS CAORF operates on a very tight schedule. Thus, delays of any kind should be kept to a minimum. If a maneuver is necessary, return to your original heading and speed as soon as possible so as to minimize the time lost, within the limits of safe navigation practice. Also maintain a safe distance from oil rig platforms and prohibited zones, as shown on the chart.

Two peloruses and a Raytheon radar system with plotting materials are available in the SS CAORF wheelhouse. At the start of the watch, the range scale selector switch will be set at 12 miles. Should you find it necessary to use the radar during the watch, you may select any range setting from 1/2 to 24 miles at any time, but you are restricted from using the 48-mile range scale. You are also restricted from using the center offset radar display mode.

Information you would normally obtain using binoculars may be requested from the bow lookout using the sound-powered telephone as follows: "Requesting information concerning a vessel at a relative bearing of ___ degrees at a range of ___ miles."

Stand the watch as you would under the same circumstances at sea. In addition, adherence to the new International Rules of the Road is required. Are there any questions before we start?

Figure F-3. Watch Orders - A1V

It is now 0900 hours and you are about to resume the 0800 to 1200 watch. The SS CAORF has been steaming during the time you were not in the wheelhouse.

The present situation is as follows:

Ownship Position (0900 Loran fix)	28^{O}14.0' North latitude 92^{O}55.11' West longitude
<u>Course</u>:	142^{O} True
Speed:	15 Knots

Two vessels have been sighted as follows:

1) About 3 points off the starboard bow at a range of approximately 5 miles and its bearing appears to be opening to the right.

2) About 3 points abaft the port beam at a range of about 6 miles and its bearing appears to be opening to the left.

Your watch orders are the same as before.

Any questions before we begin?

Figure F-4. Watch Orders - A2V

on the 12-mile scale of the radar at the start of a segment (e.g., figure F-4), the staff experimenter stood by as the initial contacts were identified (visually and on radar) and marked on the reflection plotter, at the discretion of the watch officer. This procedure assured that the radar and visual equipment was functioning prior to the start of the segment. The experimenter also reviewed the watch orders with the subject making use of the navigational chart on the bridge. It should be noted that for the purposes of experimental fidelity, the staff experimenter left the bridge prior to the start of the run.

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